Wi-Fi All-Channel Analyzer

Sergio Barrachina-Muñoz, Boris Bellalta, Edward Knightly

Universitat Pompeu Fabra Barcelona

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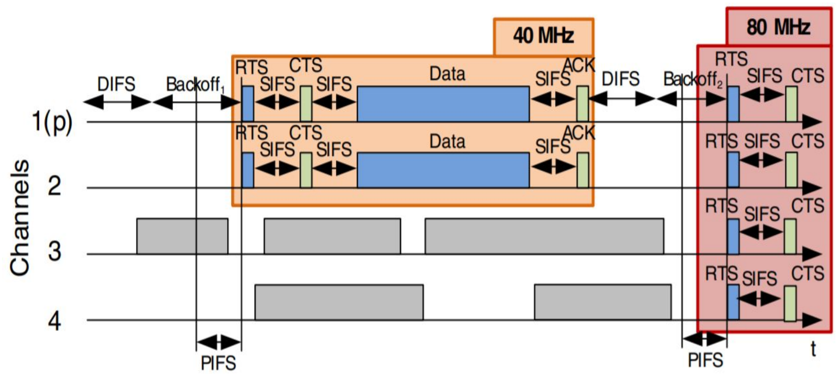
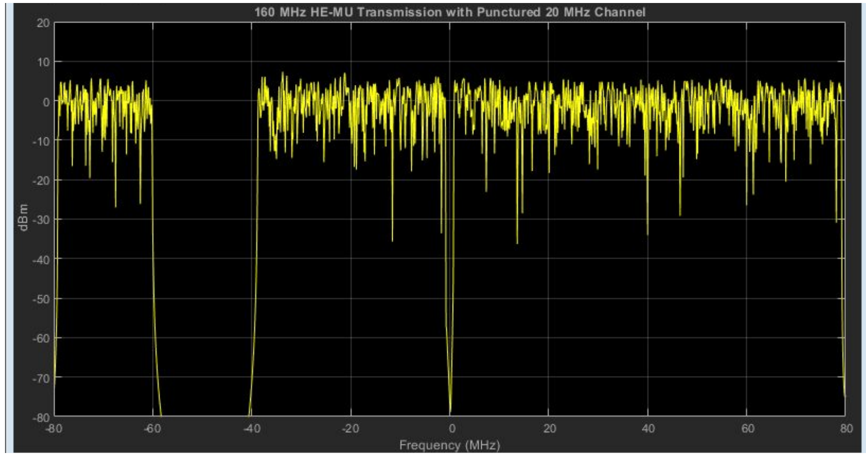
Multi-channel access for 5-GHz WLANs

- Dynamic channel bonding (e.g., [1,2])
- Preamble puncturing: non-contiguous ch. agg.
- OFDMA (e.g., [3])



CSMA/CA & dynamic channel bonding.



160 MHz signal with 20 MHz puncturing

[1] Deek, L., Garcia-Villegas, E., Belding, E., Lee, S. J., & Almeroth, K. (2014). Intelligent channel bonding in 802.11 n WLANs. IEEE Transactions on Mobile Computing, 13(6), 1242-1255.
[2] S. Barrachina-Muñoz, F. Wilhelmi, and B. Bellalta. Dynamic channel bonding in spatially distributed high-density WLANs. IEEE Transactions on Mobile Computing, 19(4):821–835, 2019
[3] Bankov, D., Didenko, A., Khorov, E., & Lyakhov, A. (2018, May). OFDMA Uplink Scheduling in IEEE 802.11 ax Networks. In 2018 IEEE International Conference on Communications (ICC) (pp. 1-6). IEEE.

Contributions of the paper

- **RQ**:
  a. Spectrum status in the WiFi 5-GHz band?
  b. Potential of efficiency increase using *channel aggr*.?

- **Contributions**:
  a. Design of *WiFi All-Channel Analyzer* (WACA)
  b. Extensive measurement campaigns
     - +10 on-field locations (two continents)
       - *Camp Nou* included
       - Controlled testbed on channel bonding
     - Heterogeneous applications (beyond WiFi)
     - Open dataset
  c. Evaluation
     - Trace-driven framework
     - Use case: cont. vs. non-cont channel bonding

GitHub

https://github.com/sergiobarra/WACA_WiFiAnalyzer

zenodo

https://www.upf.edu/web/wnrg/wn-datasets

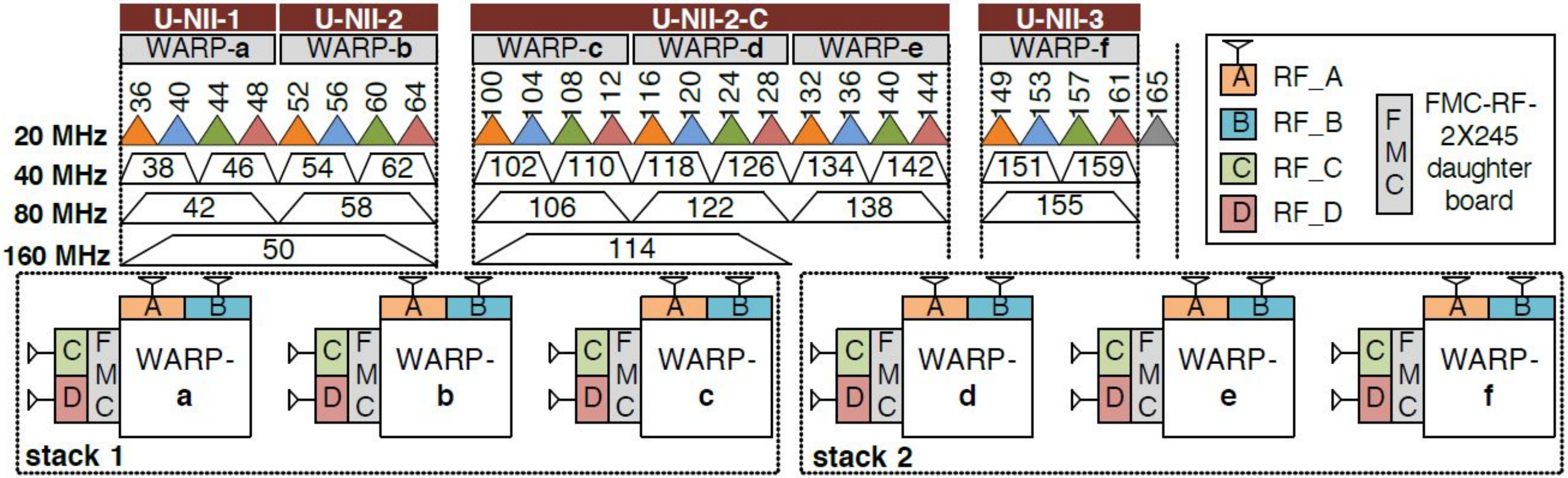
A first-of-its-kind dataset

WiFi spectrum measurements	Multi-channel benchmarking
(-) ***Few*** multi-channel spectrum measurements (e.g., [4, 5, 6, 7]). **(-)** Via ***sequential*** scanning. **(+)** WACA measures all channels ***simultaneously***.	**(-)** Experimental results target on one or ***few*** controlled links. **(-)** Simulation results make (reasonable) ***assumptions***. **(+)** WACA measures ***unlimited*** BSS's in ***real*** operational.

[4] Vinod Kone, Lei Yang, Xue Yang, Ben Y Zhao, and Haitao Zheng. 2010. On the feasibility of effective opportunistic spectrum access. In Proceedings of the 10th ACM SIGCOMM conference on Internet measurement. 151–164.
[5] Vinod Kone, Lei Yang, Xue Yang, Ben Y Zhao, and Haitao Zheng. 2012. The effectiveness of opportunistic spectrum access: A measurement study. IEEE/ACM Transactions on Networking 20, 6 (2012), 2005–2016.
[6] Michael Rademacher, Karl Jonas, and Mathias Kretschmer. 2018. Quantifying the spectrum occupancy in an outdoor 5 GHz WiFi network with directional antennas. In 2018 IEEE Wireless Communications and Networking Conference (WCNC). IEEE, 1–6.
[7] Sixing Yin, Dawei Chen, Qian Zhang, Mingyan Liu, and Shufang Li. 2012. Mining spectrum usage data: a large-scale spectrum measurement study. IEEE Transactions on Mobile Computing 11, 6 (2012), 1033–1046.

WACA: a 5-GHz all-channel analyzer

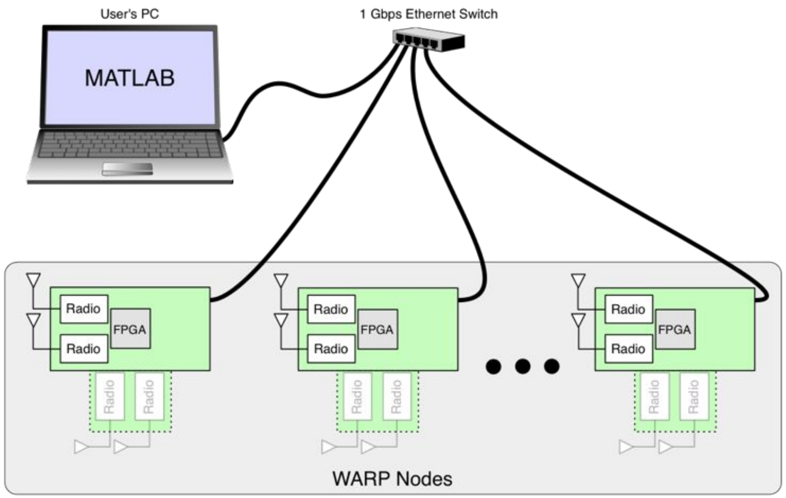
- Components:
  - x6 WARPs (x2 RFs each: A & B)
  - x6 FMC daughter boards (x2 extra RFs each: C & D)
  - x24 5-GHz antennas (one for each 20-MHz channel)



Channel allocation to the 24 RFs

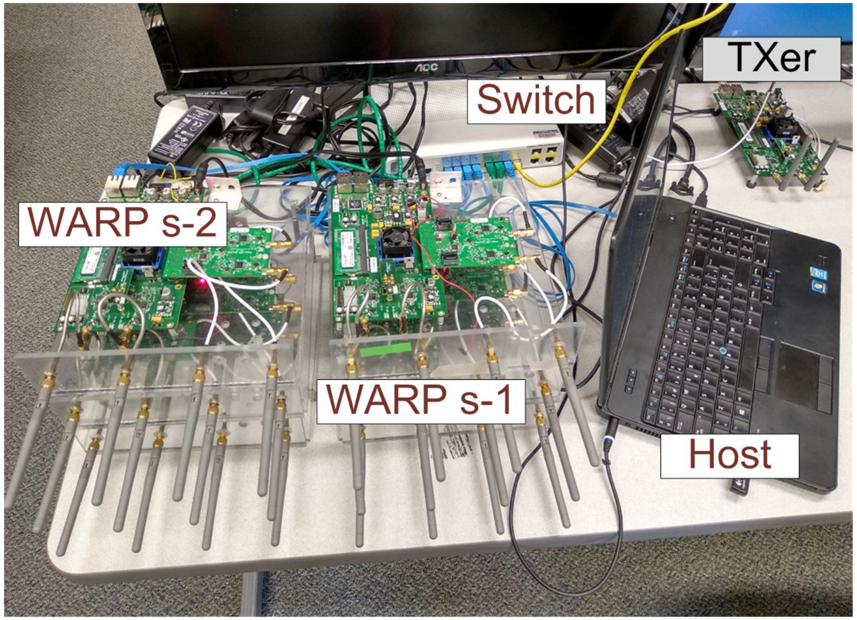
WACA topologies

Logical topology



WARPLab implementation overview.

Physical topology



Deployment schematic.

Timeline diagram

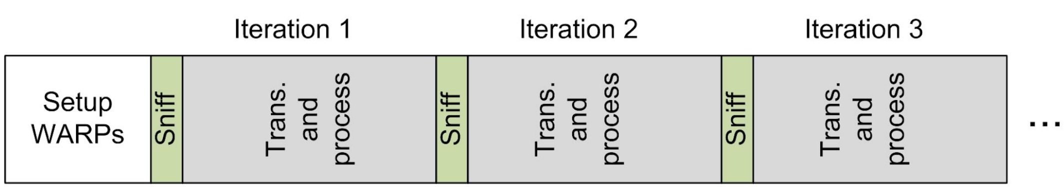
Deploy system | **Set up** | **Run/Monitor** | **Post-process**

1. Deploy switch and WACA
2. Eth. cable for the host: 1 Gbps
3. Check connectivity (ARP tables)

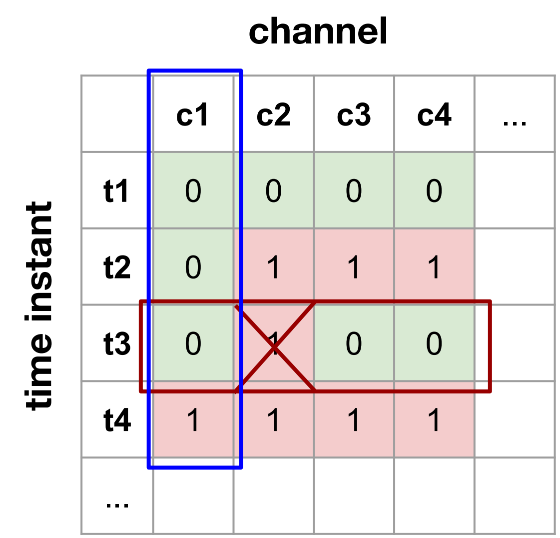
- No. of iterations
- Sniffing time
    - **x1 sec** → 70 MB
    - x1 min → 4.2 GB
- Downsampling
    - 10 us

- Check **at least** the first iterations
- Multiple sources of failure
    - Cables
    - Memory

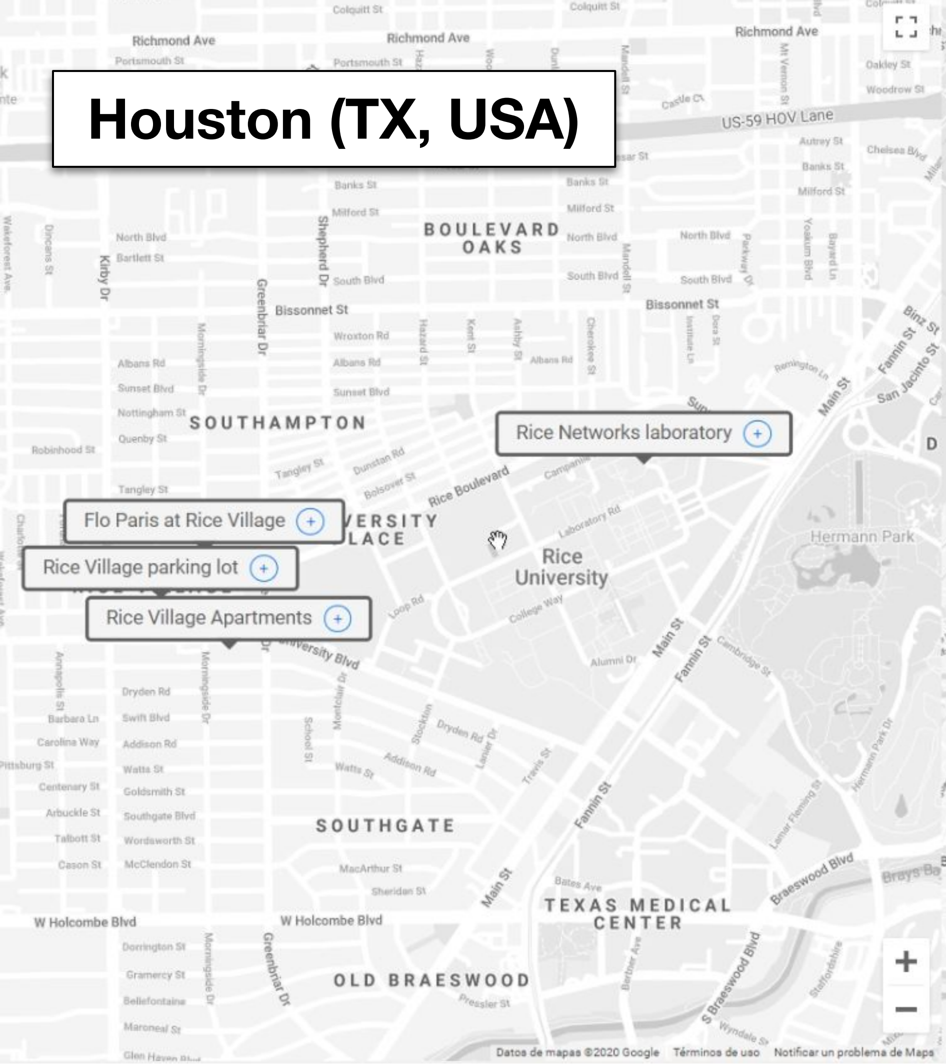
- Statistics
- Trace-driven sims

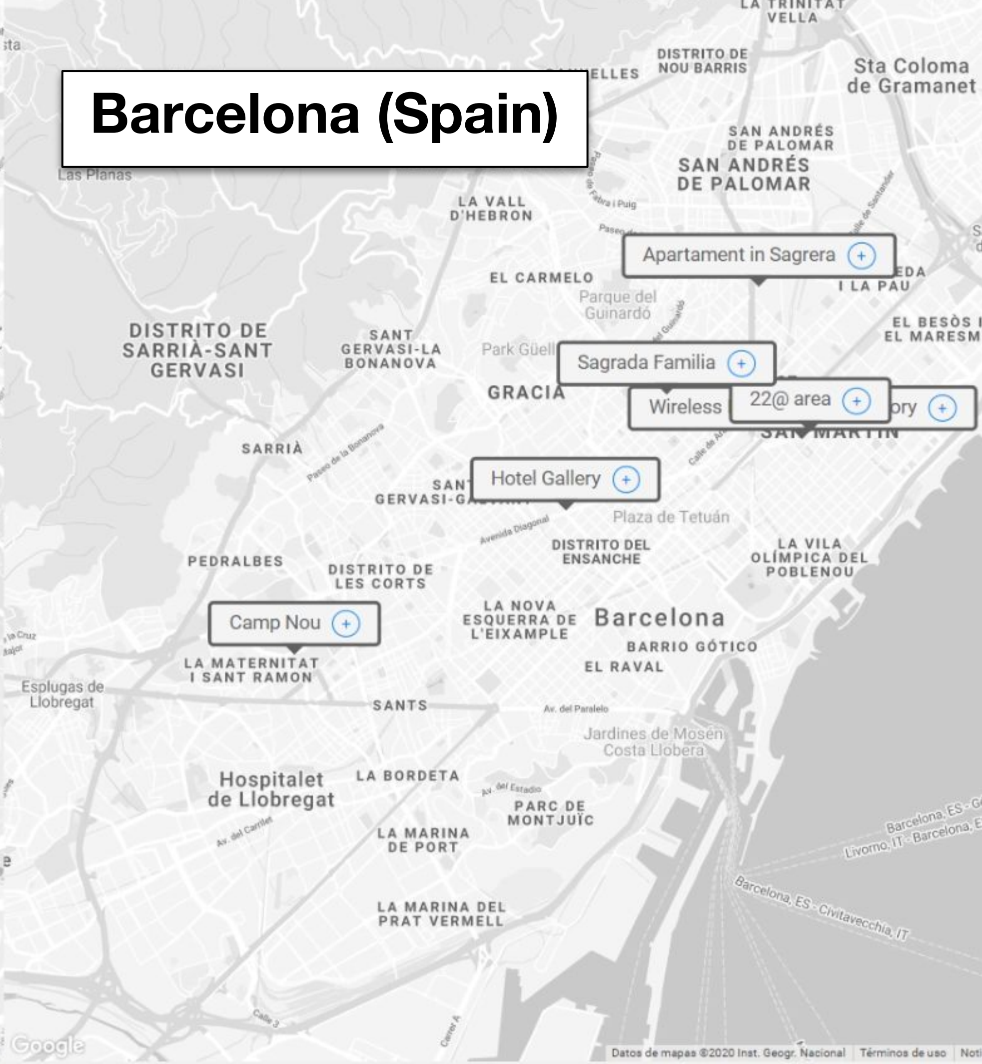


WACA iterative process.

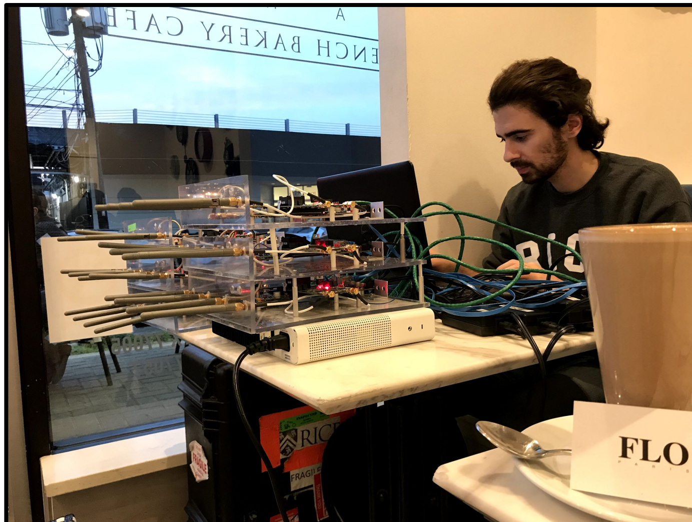


Traces (occupancy matrix).

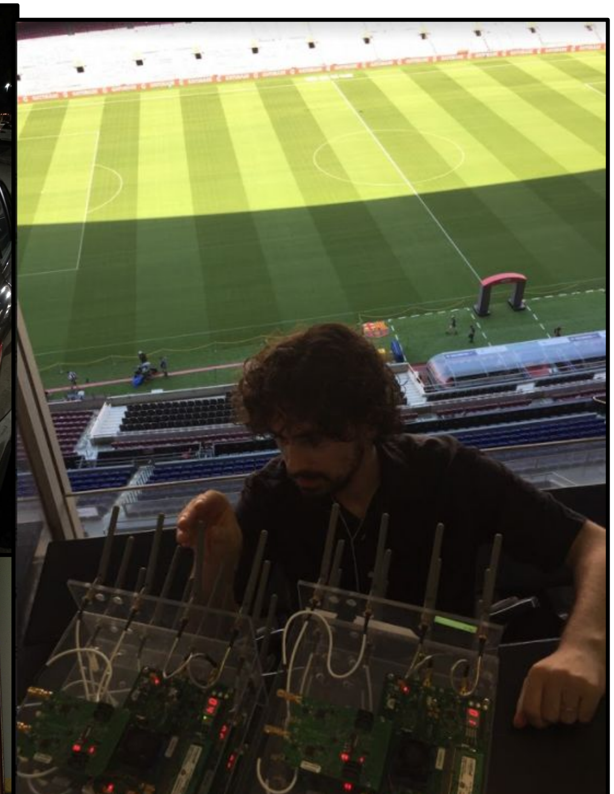




Measurement campaigns

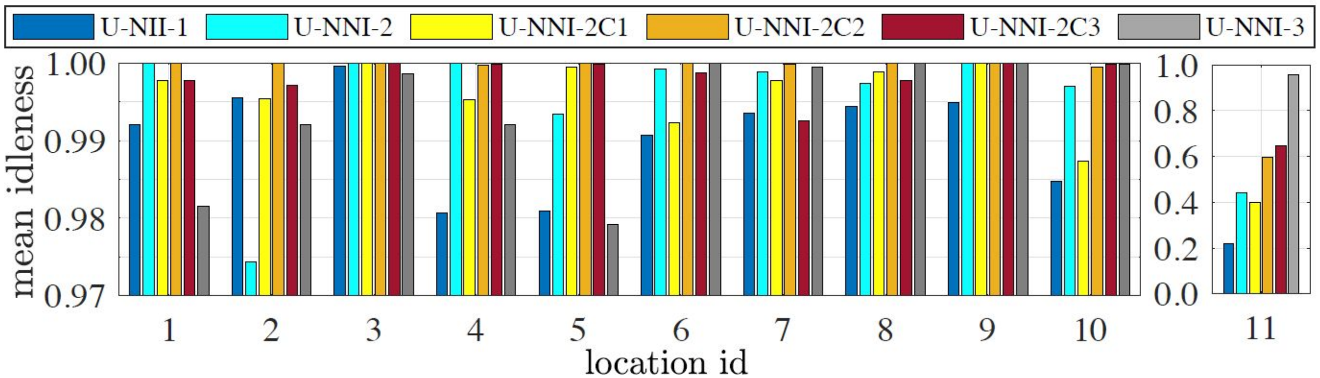

FLO


STOP



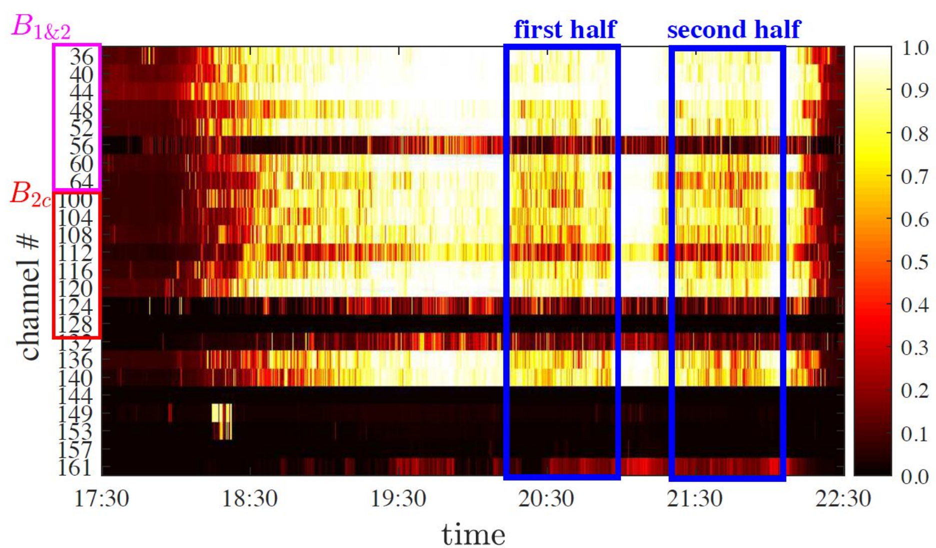
How does the spectrum look like?

Spectrum is mostly empty (**on average**)!



Mean idleness per sub-band.

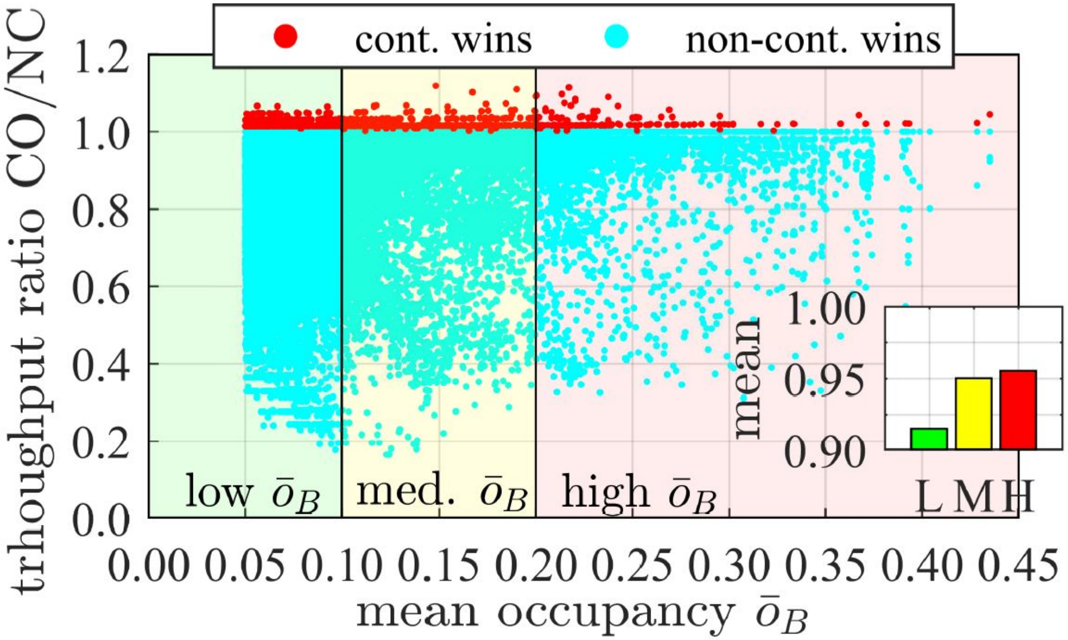
Camp Nou stadium is a world apart (peaks of 99% occupancy)



Occupancy spectrogram at Camp Nou stadium.

Contiguous vs. non-contiguous CB

Focus on epochs of high activity → emulate future deployments



Throughput ratio of contiguous vs. non-contiguous channel bonding. The bar chart inset depicts the mean aggregated ratio for low (L), medium (M), and high (H) occupancy regimes.

Conclusions and future work

- WACA to measure whole Wi-Fi's 5-GHz band simultaneously
  - Power *screenshots* of all the channels at the same time
- Extensive measurement campaigns (including Camp Nou)
- The spectrum is empty (on average) most of the time
  - Camp Nou is an exemption
- Trace-driven framework to evaluate multi-channel solutions
  - Use case: contiguous vs. non-contiguous channel bonding

- **Future work**:
  - Analysis of key factors like spectral correlation, IEEE 802.11ax policies, or bandwidth prevention as future work

Any questions?

?

Sergio Barrachina-Muñoz

sergio.barrachina@upf.edu

Ph.D. candidate

Wireless Networking (WN) research group

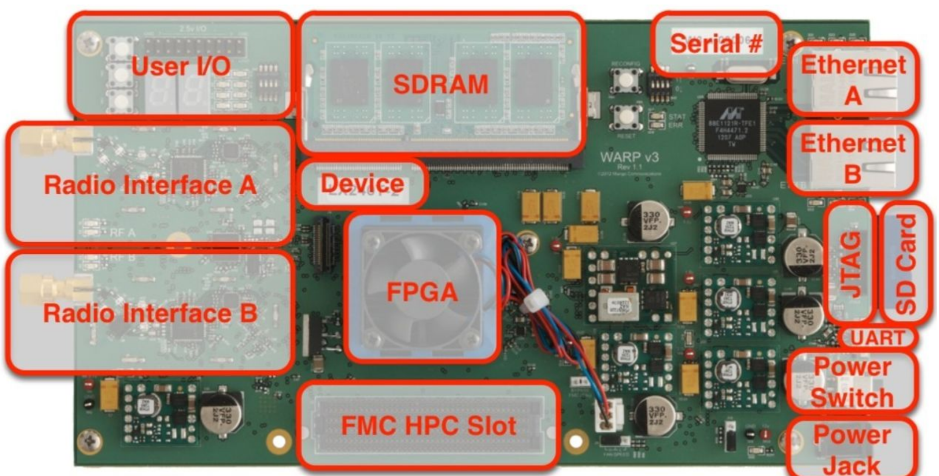
Universitat Pompeu Fabra, Barcelona

APPENDIX.

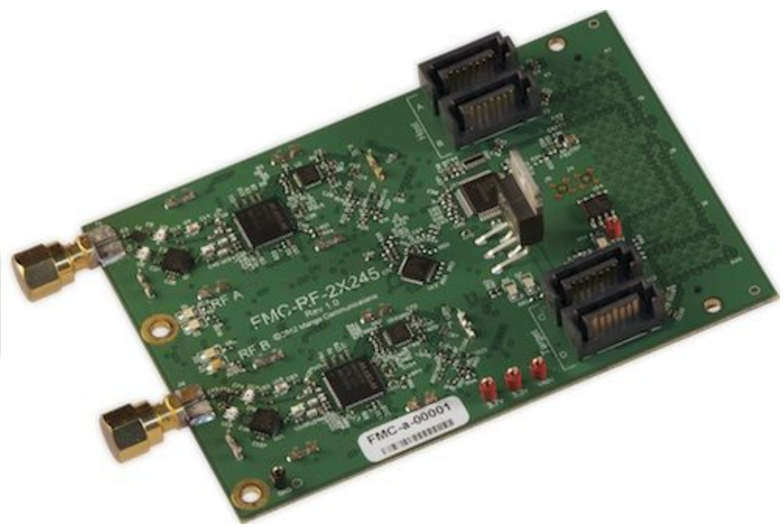
BACKUP SLIDES

The WARP board

- Commercialized by Mango Communications
- WARP v3 [8] is the latest generation of WARP
  - Integrates a Virtex-6 FPGA
  - 2 programmable RF interfaces
  - Variety of peripherals



Key components of WARP v3



FMC-RF-2X245: Dual-Radio FMC Module

Alternatives for simultaneous measuring

~700 MHz to be **simultaneously** sniffed

Spectrum analyzer

- High BW analyzers are expensive.
- Resolution (bin size) tends to decrease as BW increases.
- *Difficulty* in gathering historic data.

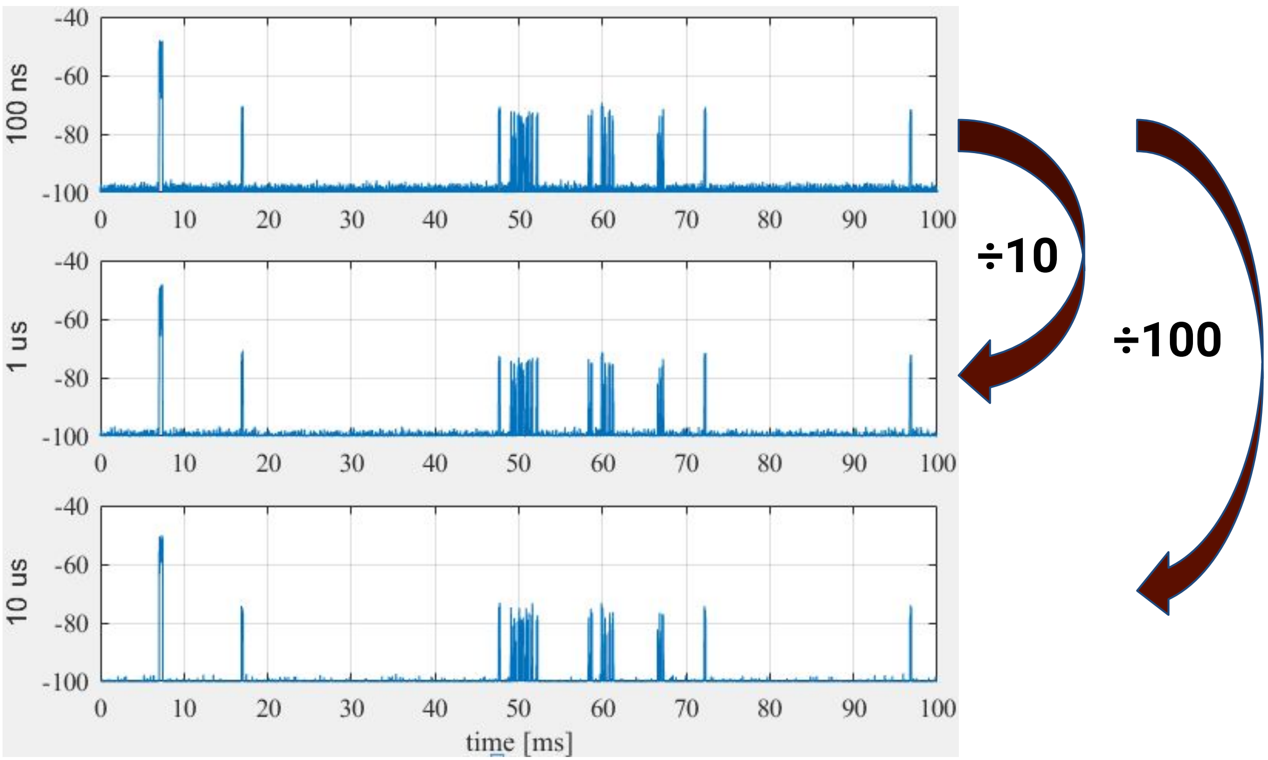
Multiple wireless cards

- x24 wireless cards required.
- Synchronization and management issues.
- Connectivity bottleneck (USB).
- OS RAM issues?

Channel sweeping is **not** an option!

Downsampling to reduce memory

- Downsampling for saving memory
  - 1 RSSI sample every 10 us is enough for WiFi (T_SIFS < 16 us)
  - We decrease memory by a x100 factor

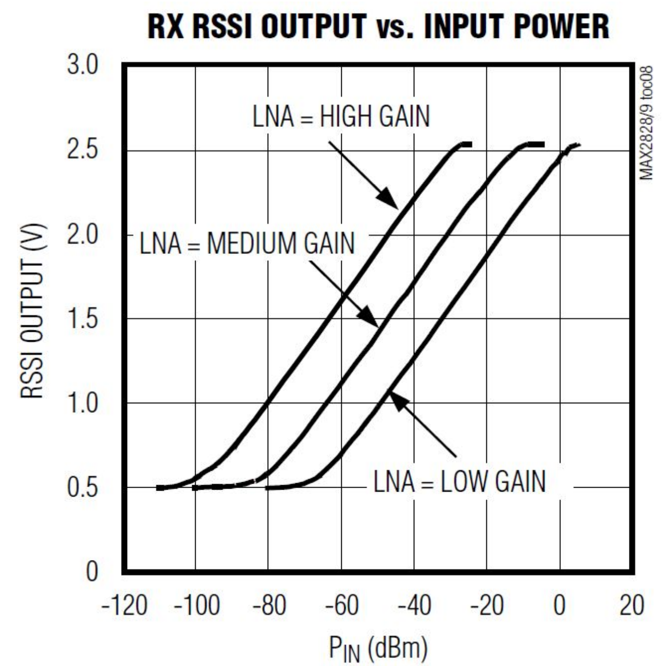


RSSI curves for different downsampling factors

CCA assessment: from RSSI to power

- **MAX2829** transceiver:
  - Provides a 10-bit RSSI
  - Values: [0, 1023]
- Power depends on the waveform:
  - Mapping Power(RSSI) provided for 802.11g 20 MHz waveforms
- CCA assessment:

$$\text{busy} = \begin{cases} \text{true} & \text{if } P_{\text{rx}} \geq \text{CCA} \\ \text{false} & \text{otherwise} \end{cases}$$



Power received vs. RSSI for 802.11g waveforms according to MAX2829 datasheet.