Institute for the Wireless Internet of Things
at Northeastern University

Making the Case for Open, Softwarized, Data-Driven 802 Networks

Francesco Restuccia
Assistant Professor
Electrical and Computer Engineering
Associate Faculty, WIOT and Roux Institute
Northeastern University, United States
Email: frestuc@northeastern.edu
Website: https://restuccialab.org

DCN: 1-21-0078-02-ICne

Disclaimer

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- My field is **wireless** comms and systems
  - I can mainly speak from that perspective
- Similar concepts can be applied to wired networks
- Any feedback is mostly appreciated

The Quest for Wireless Performance

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Autonomous driving

Smart factory

VR/AR Gaming

- New applications demand higher **BW**, lower **latency**
- **Edge** computing is becoming more and more necessary
- Establishing URLLC will be fundamental for **802 networks**

Main Strategy So Far?

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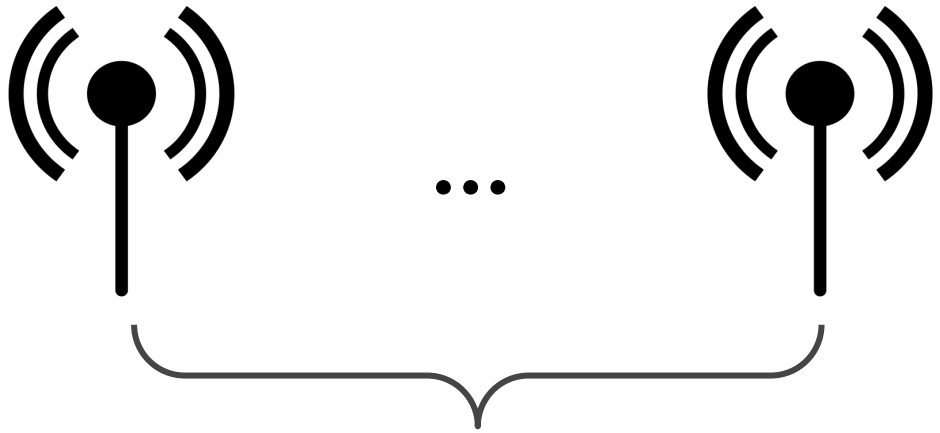
- Increase Bandwidth (2x)

160 MHz (802.11ax)

320 MHz (802.11be)

- Increase Spatial Streams (2x)



16 Spatial Streams
4 SS per STA

Garcia-Rodriguez, Adrian, et al. "IEEE 802.11 be: Wi-Fi 7 Strikes Back." *IEEE Communications Magazine* 59.4 (2021): 102-108.

Spectrum Bandwidth @ 6 GHz

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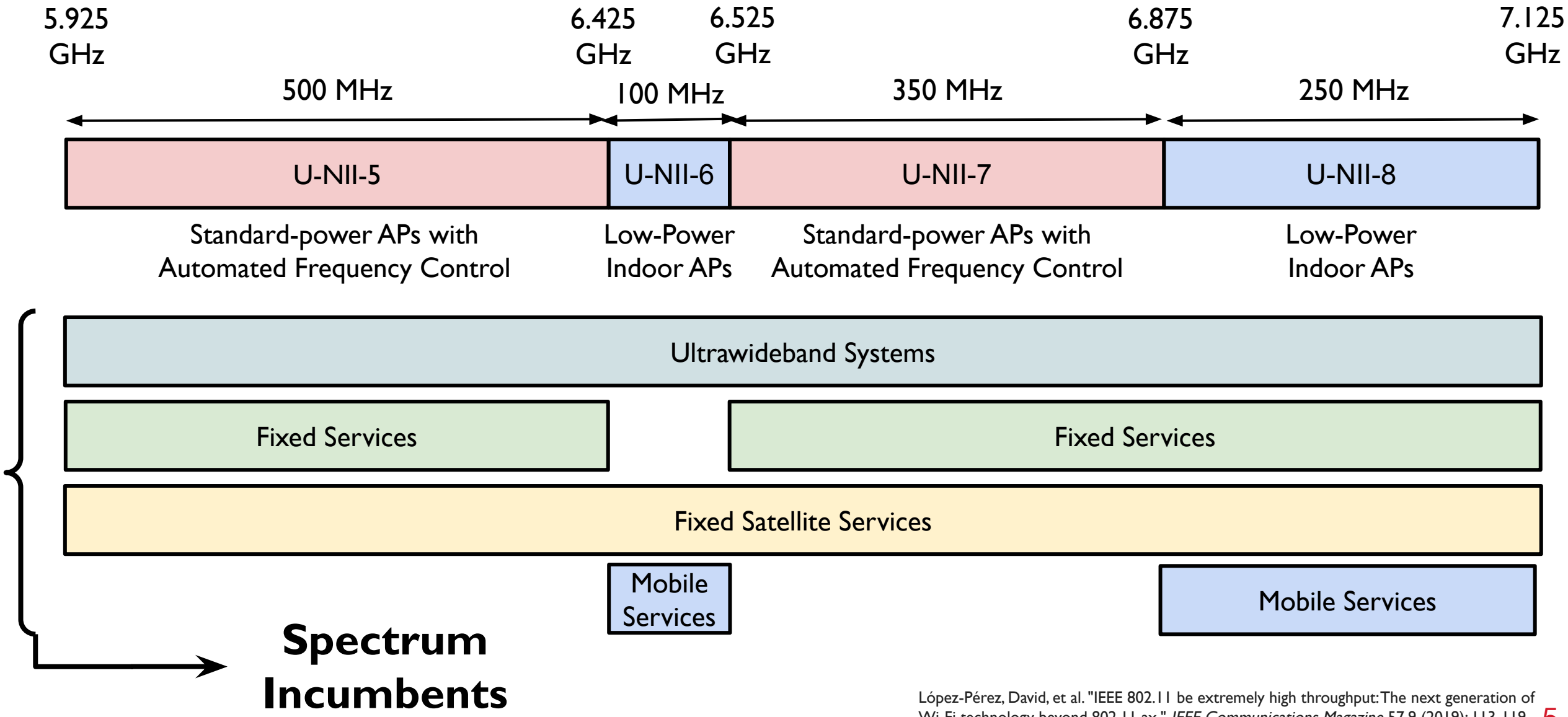

López-Pérez, David, et al. "IEEE 802.11 be extremely high throughput: The next generation of Wi-Fi technology beyond 802.11 ax." *IEEE Communications Magazine* 57.9 (2019): 113-119.

Is this enough as a Long-term Strategy?

Complex and Crowded Spectrum

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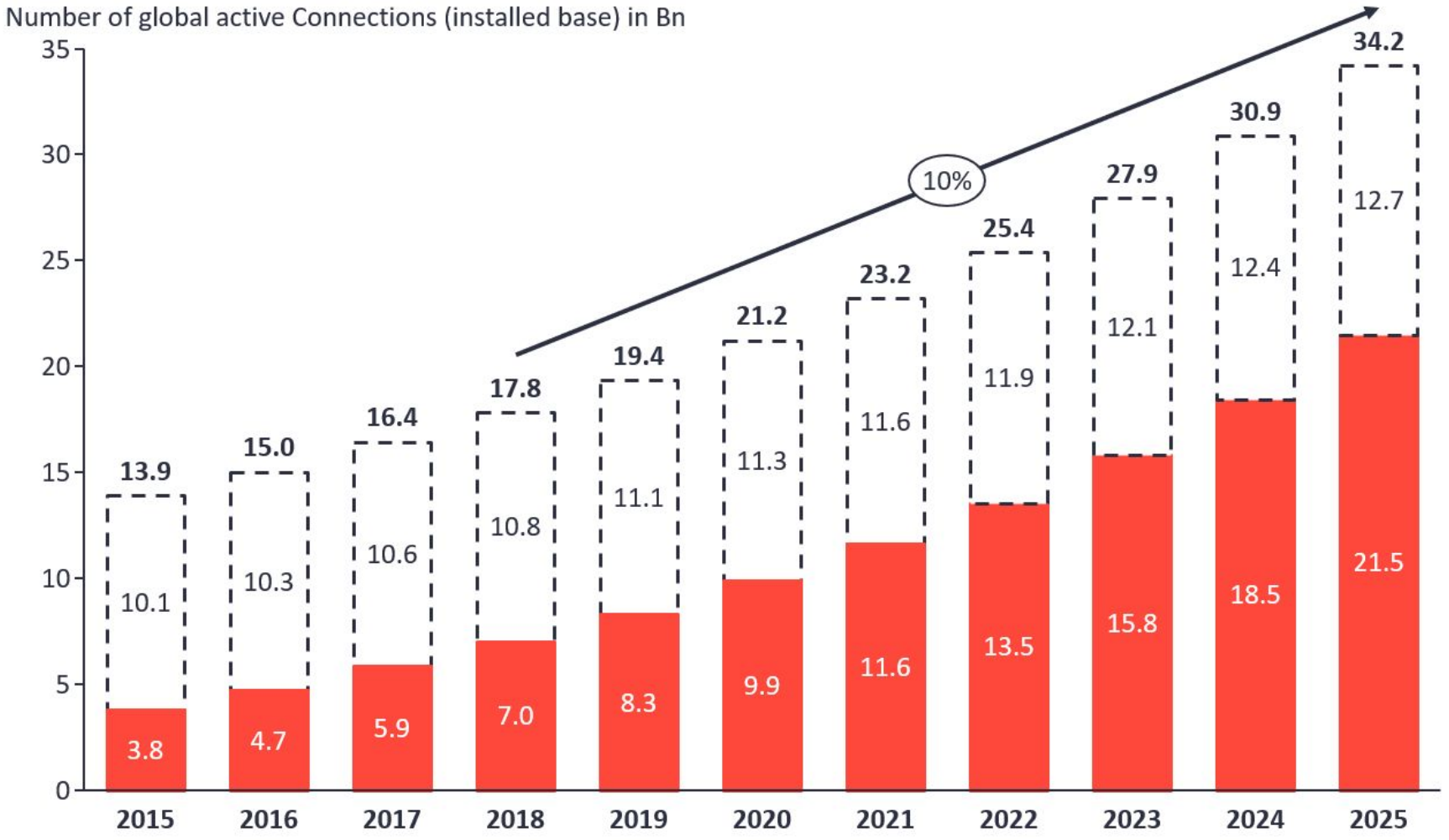
> 4x Human Population!



Note: Non-IoT includes all mobile phones, tablets, PCs, laptops, and fixed line phones. IoT includes all consumer and B2B devices connected – see IoT break-down for further details
Source: IoT Analytics Research 2018

Huge BW Implies Need for Spectrum Sharing

Increased Complexity for MIMO

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CSI Feedback Overhead

- 8x8 MU-MIMO network at 160 MHz
  - 486 subcarriers x 56 angles/subcarrier x 16 bits/angle ~ **53 kB**
- Every 5ms, airtime overhead is 435,456 / 0.05 = **1.088 Mbit/s**

Increasing Inter-Stream and Inter-User Interference

- More users and more SS, more frequent CSI probes

This results in increased HW cost
LESS SALES!

M. S. Gast, "802.11ac: A Survival Guide: Wi-Fi at Gigabit and Beyond," O'Reilly Media, Inc.", 2013

To Summarize

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Throwing more BW and SS is likely not to be enough as a long-term strategy

Real-time AI-driven techniques will become fundamental to deal with the increased spectrum complexity

What are other communities doing about this?

Open and Virtualized 5G network

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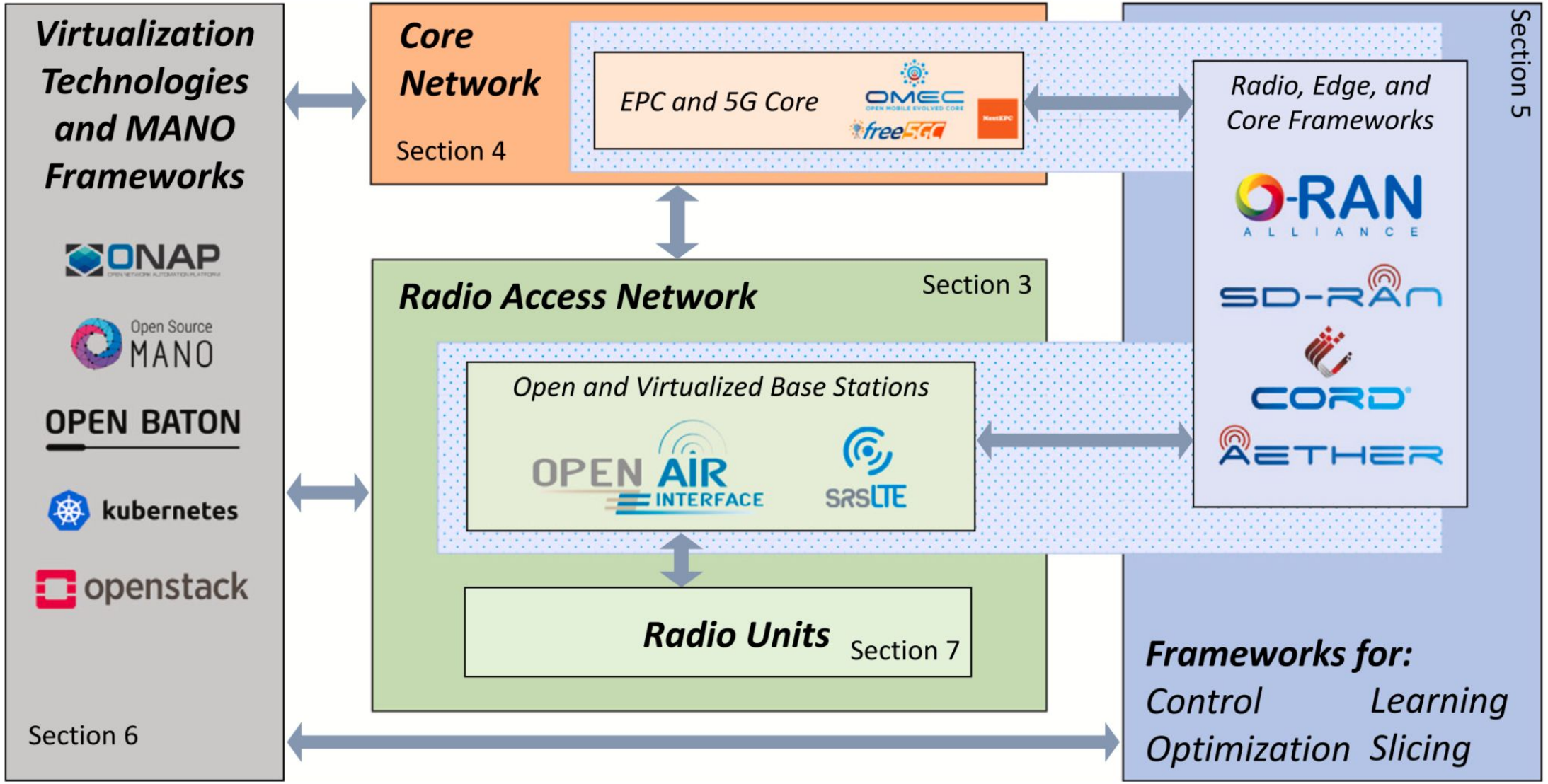

Bonati et al., "Open, Programmable, and Virtualized 5G Networks: State-of-the-Art and the Road Ahead," Computer Networks 182 (2020).

The O-RAN Paradigm

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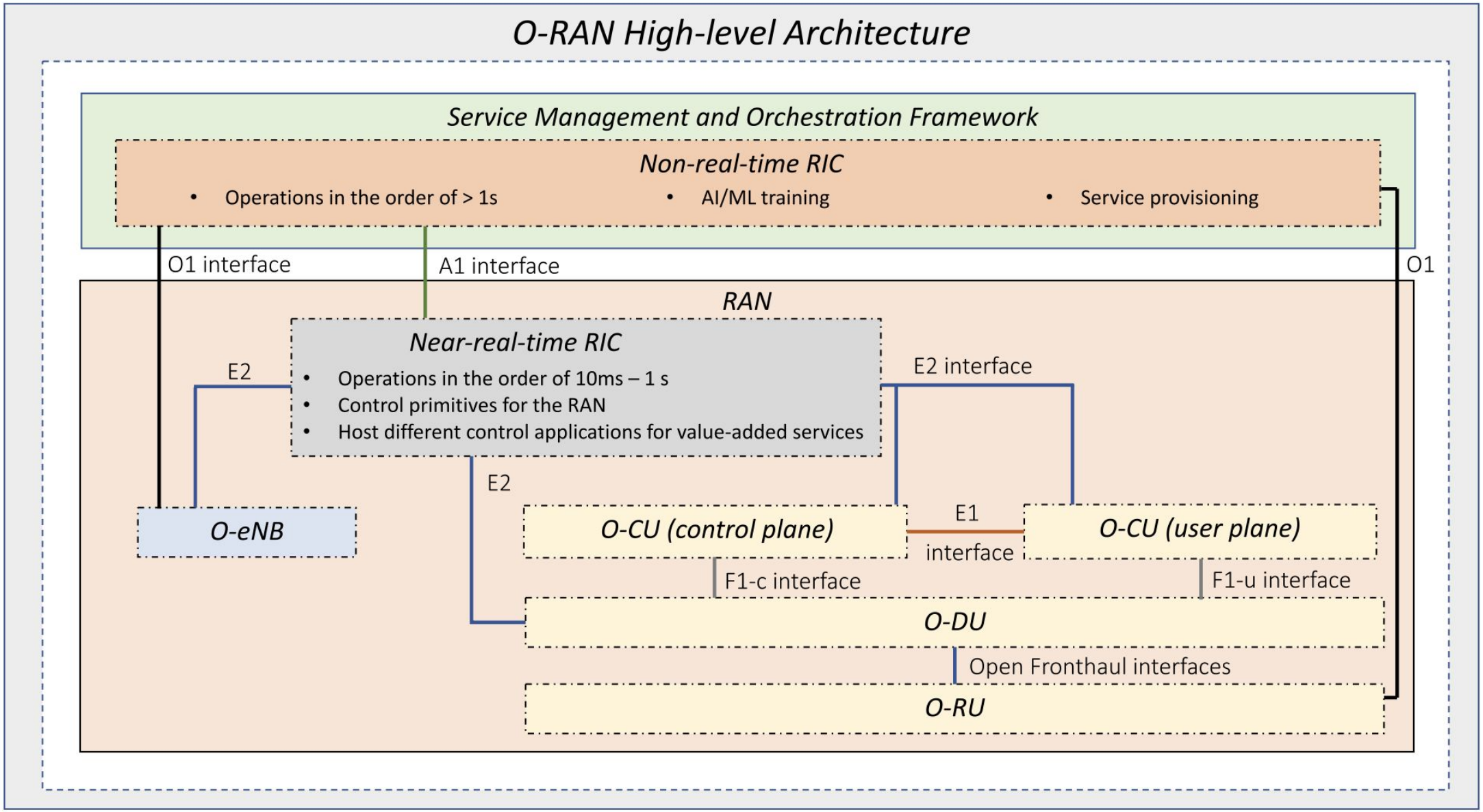

Openness Enables Full-Stack AI-based Control

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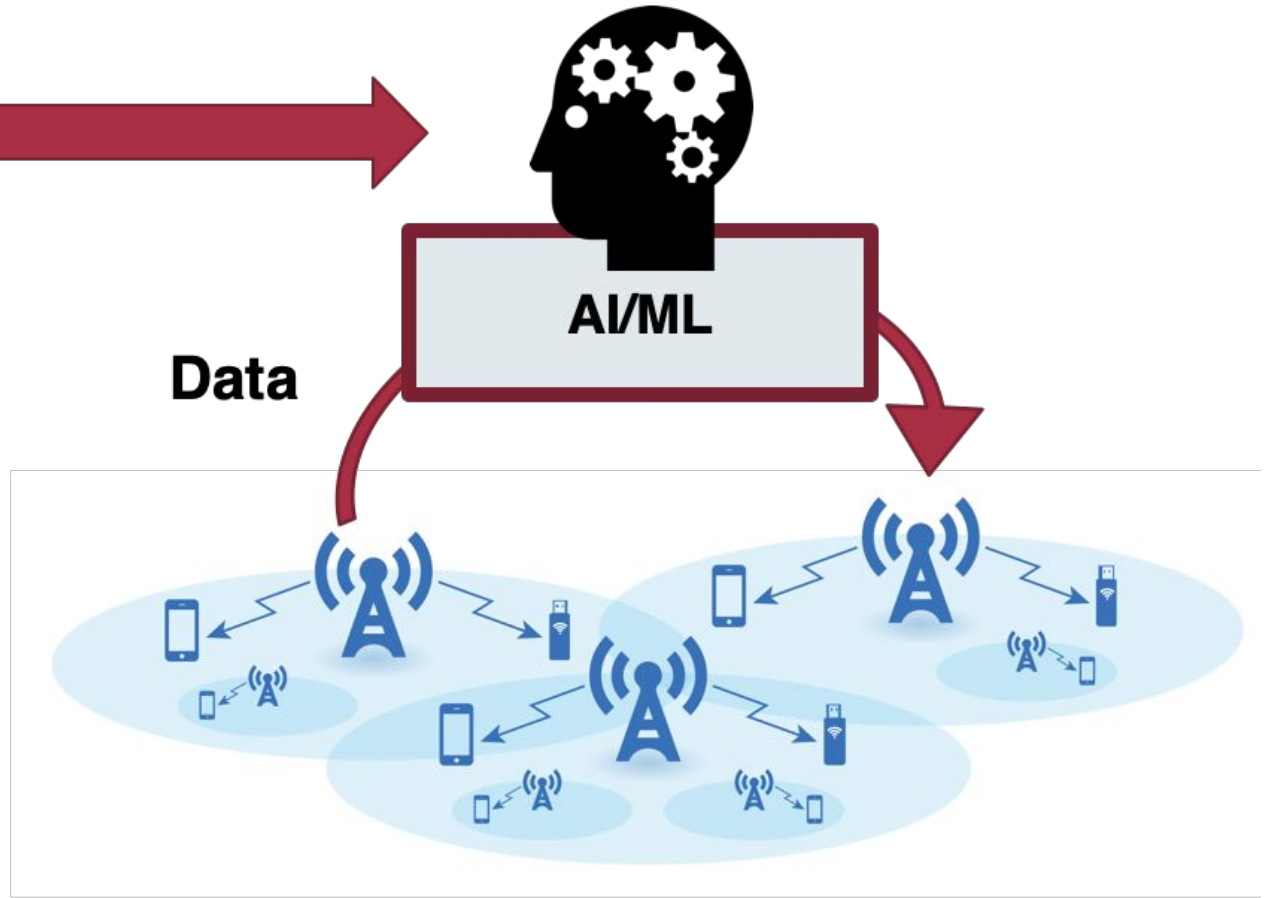
I need to stream 4K video to 100 users in Times Square, NY from 8pm to 9pm



- **Automated** software generation
- **Intent recognition**
- **Adapt** to network state and traffic demand
- **Best performance**
- **Zero-touch reconfiguration**

Advantages of Open, Virtualized Networks

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1. Disaggregation of **hardware** and **software** possible
2. AI operations can be integrated **by design** into the network
3. Interoperability enables diversity and **reduces CAPEX (60%)**
4. **Future-proof** – no rip and replace infrastructure
5. Easier maintenance results in **reduced OPEX (65%)**
6. Faster deployments, higher throughput, coverage and capacity

O-RAN market is estimated to attain a revenue of USD 419.51 Million in 2021 and USD 21,371.47 Million in 2028, CAGR of 83.1%

https://www.researchnester.com/reports/open-radio-access-network-market/2781

Parallel Wireless, "OpenRAN – 7 vital benefits for MNOs," https://www.parallelwireless.com/blog/openran-7-vital-benefits-for-mnos/

Consequences?

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Better service to the final customer

Mobile subscriptions costs going down

802 standards could become obsolete

How do we fill the current gap?

Dealing With Complexity: AI Techniques

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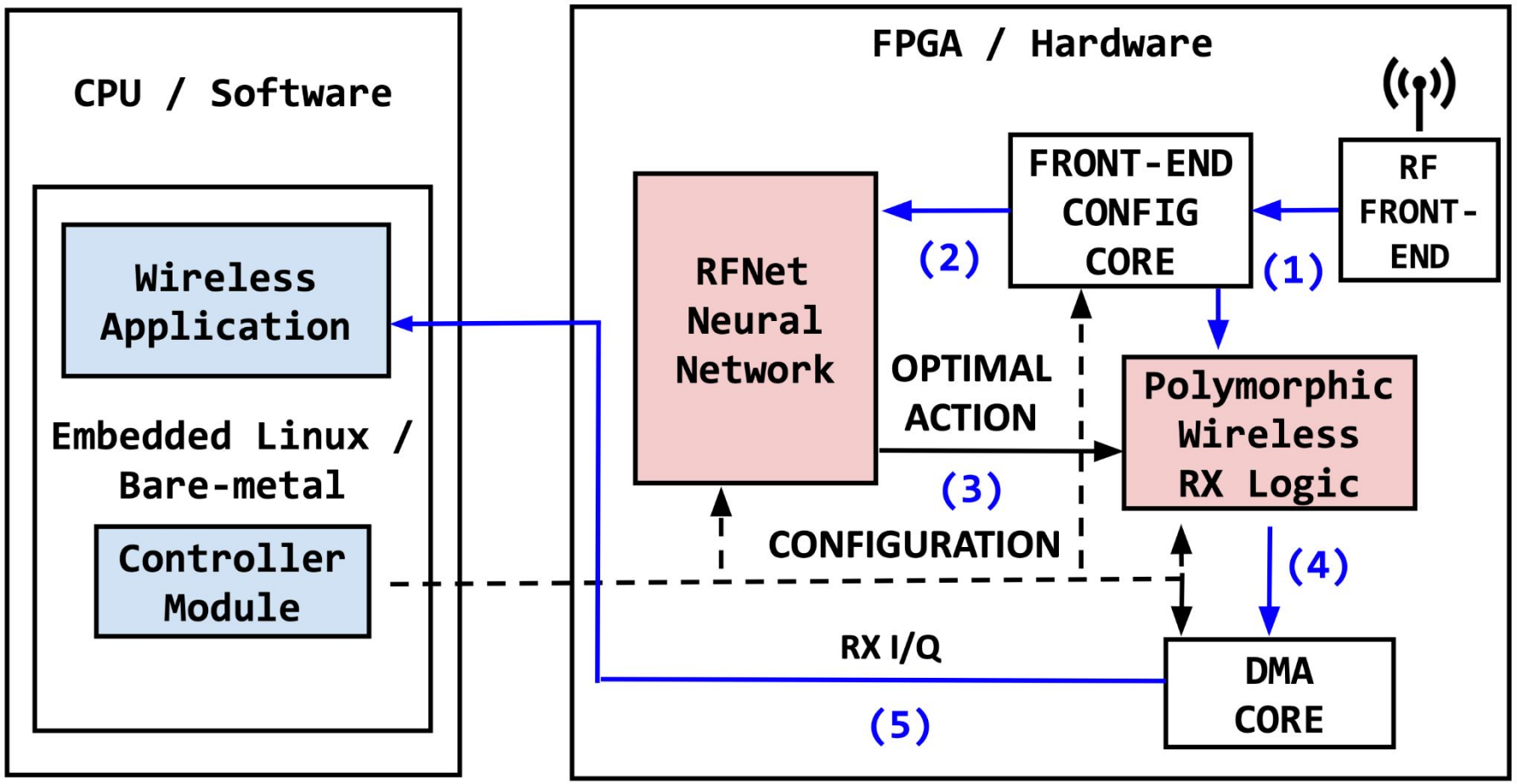

17x less latency

15x less energy

F. Restuccia and T. Melodia, "Big Data Goes Small: Real-Time Spectrum-Driven Embedded Wireless Networking Through Deep Learning in the RF Loop," **IEEE INFOCOM 2019**

AI Techniques for Zero-Touch Network Control

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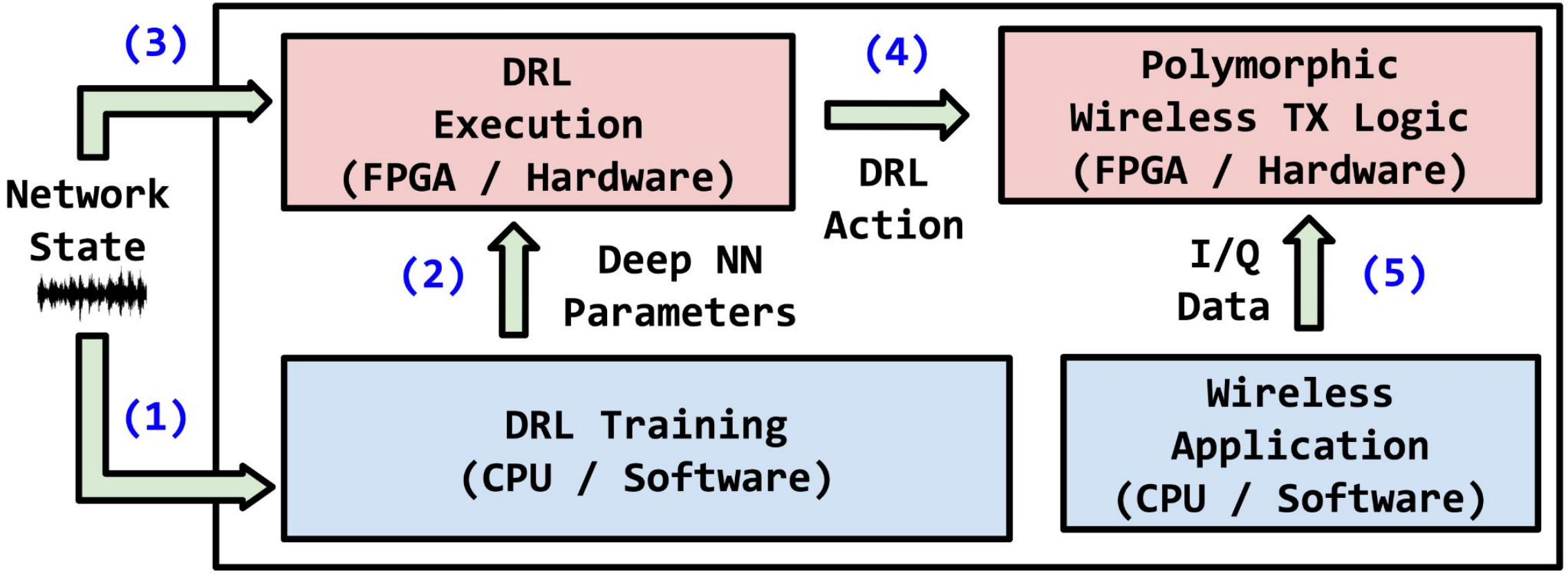

F. Restuccia and T. Melodia, "DeepWiERL: Bringing Deep Reinforcement Learning to the Internet of Self-Adaptive Things," **IEEE INFOCOM 2020**

Spectrum Sharing b/w Wi-Fi and 5G

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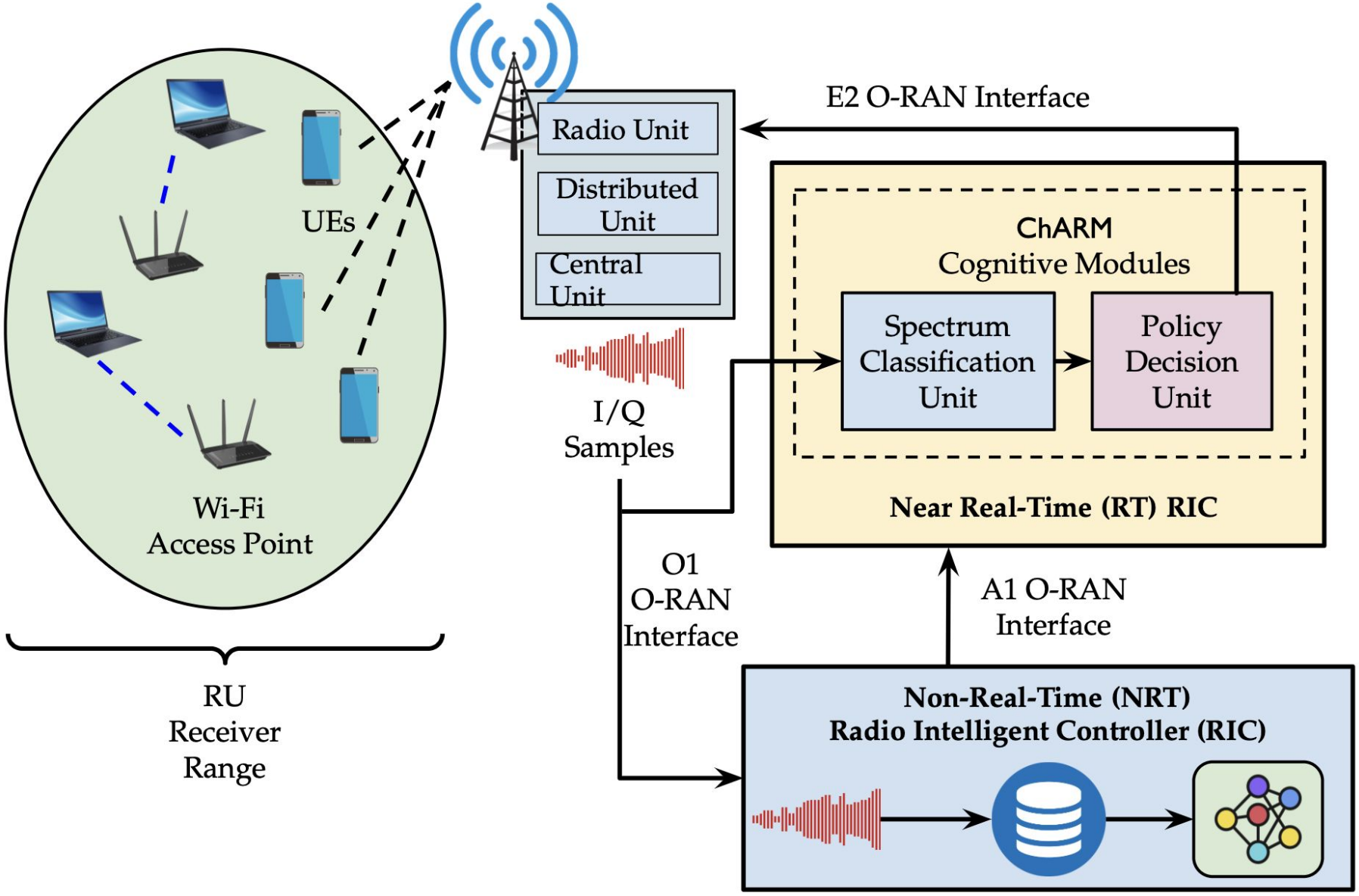

L. Baldesi, F. Restuccia and T. Melodia, "ChARM: NextG Spectrum Sharing Through Data-Driven Real-Time O-RAN Dynamic Control," **IEEE INFOCOM 2022**

To Summarize

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802 networks should adopt open, softwarized strategies similar to O-RAN to remain competitive

802 networks should learn to coexist with other technologies and embed AI by design into their architecture

How can the 802 RM evolve?

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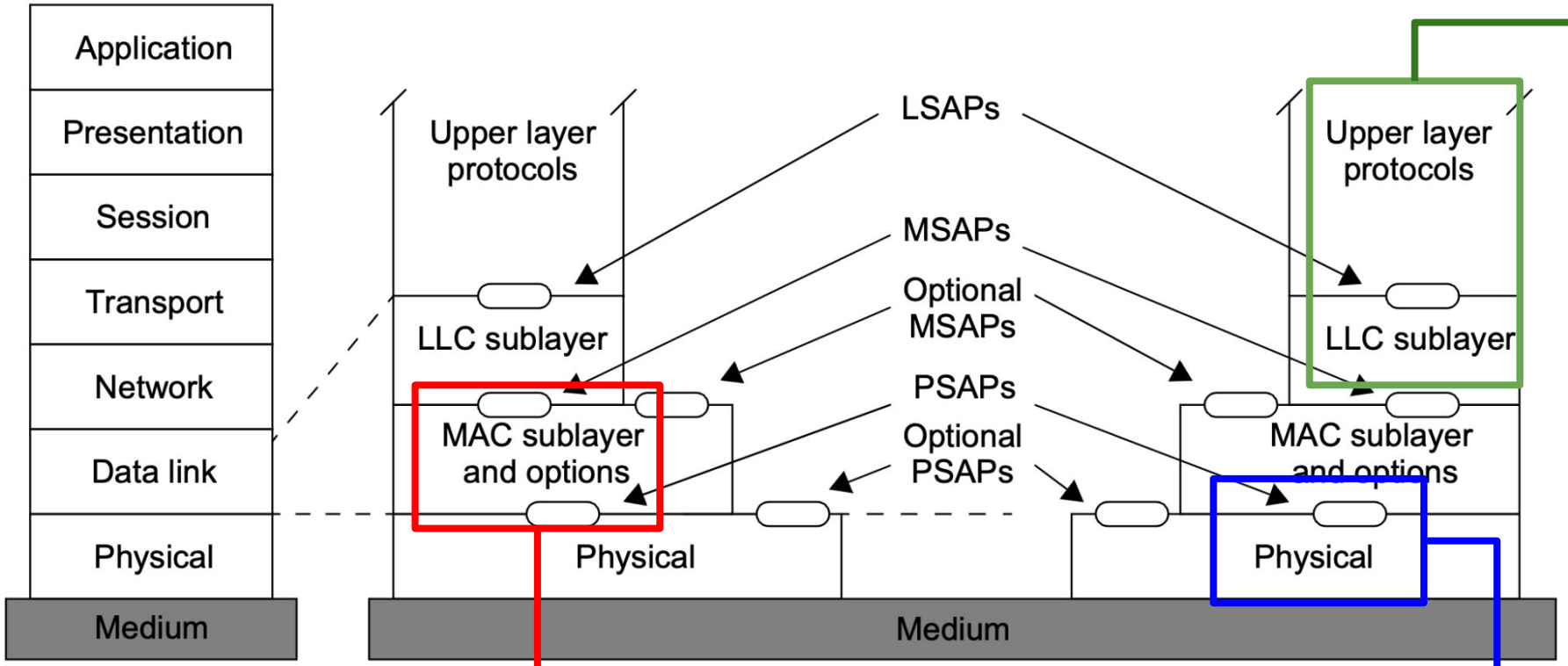

Figure 3—IEEE 802 RM for end stations

- **Modules** for distributed & centralized control of MAC/PHY,
  - for current 802 network
  - across 802 networks
  - different networks (e.g., O-RAN)
- If **centralized**, interfaces from/to central controller (e.g., AP in Wi-Fi)

Modules and Interfaces

- **Interfaces** for MAC control & monitoring (beams, modulation, coding, etc) and channel control (CSI)

- **Interfaces** for radio control & monitoring (e.g., beams, modulation, coding, etc) and channel control (e.g., CSI)

Thanks!
Questions?