N **Institute for the Wireless
Internet of Things**
at Northeastern University

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

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What is the current threat

Risk of keep doing business the way it is now

How the new 802 architecture will **drive costs down**

Emerging new markets

Enhancement of **existing** 802.11 business models

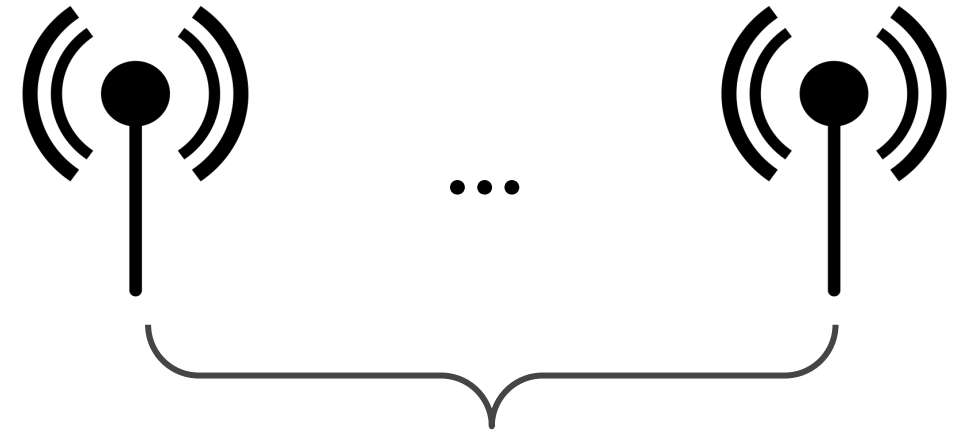New 802.11 **business opportunities**

What is the current threat?

Strategy to improve 802.11 routers?

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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

- For better performance? Is it really needed?
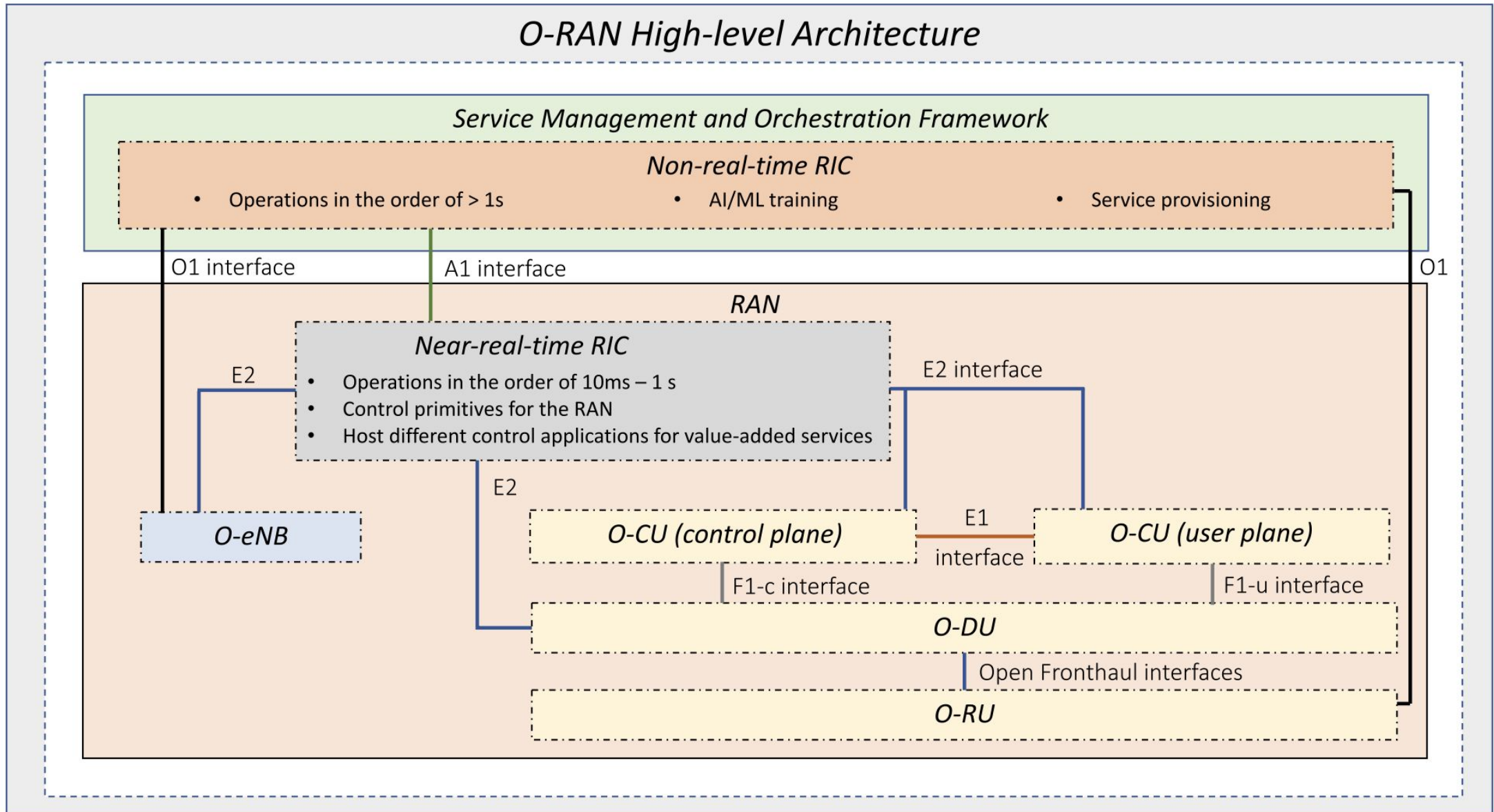- AFAIK, no 802.11ac routers that do **8x8 MIMO**! Why?

Reality Check?

- Increasing complexity

- Makes **cost** go **UP!**

COST

- Routers are becoming **very expensive**

- **With respect to a 802.11ac router**

  - A Wi-Fi 6E router is **~6x more expensive**

  - A tri-band Wi-Fi router is **~15x** more expensive

Ry Christ (CNET). Wi-Fi 6E routers are here, and we're not ready for them
https://www.cnet.com/home/internet/wi-fi-6e-routers-are-here-and-were-not-ready-for-them/

Threat:
Fewer People Buy the
New, Fancy, Expensive Routers

The O-RAN Paradigm

O-RAN High-level Architecture

Service Management and Orchestration Framework

Non-real-time RIC
- Operations in the order of > 1s
- AI/ML training
- Service provisioning

O1 interface   A1 interface   O1

RAN

Near-real-time RIC
- Operations in the order of 10ms – 1 s
- Control primitives for the RAN
- Host different control applications for value-added services

E2

E2 interface

O-eNB

E2

O-CU (control plane)   E1 interface   O-CU (user plane)

F1-c interface   F1-u interface

O-DU

Open Fronthaul interfaces

O-RU

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Openness Enables Full-Stack AI-based Control

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

AI/ML

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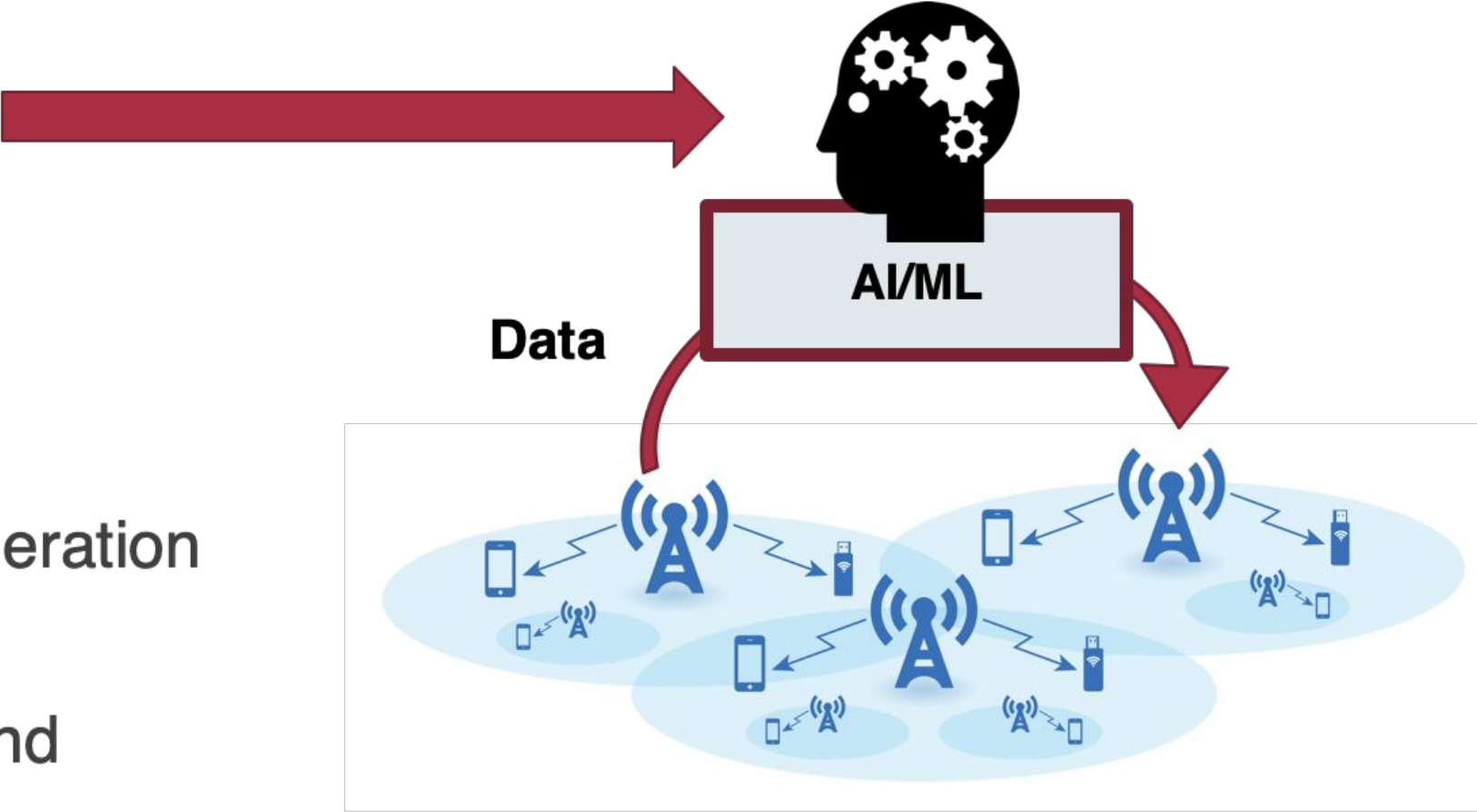
- **Automated** software generation
- **Intent recognition**
- **Adapt** to network state and traffic demand
- **Best performance**
- **Zero-touch reconfiguration**

# Advantages of Open, Virtualized Networks

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/

What If We Apply the Same Concepts?

**Do more with less antennas and BW
(SW vs HW)**

**Router costs can be contained
(why? less complexity,
less maintenance costs)**

What If We Apply the Same Concepts?

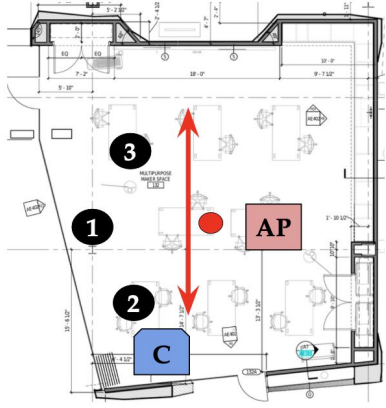# Good performance with less costs! (People will choose 802.11 and not 5/6G networks)
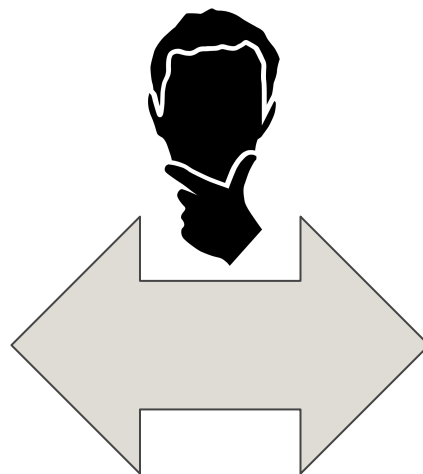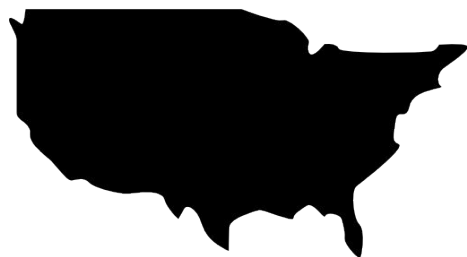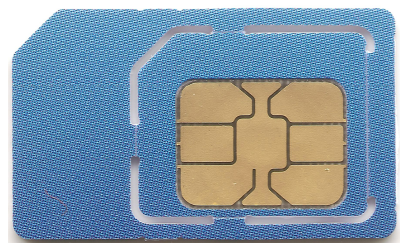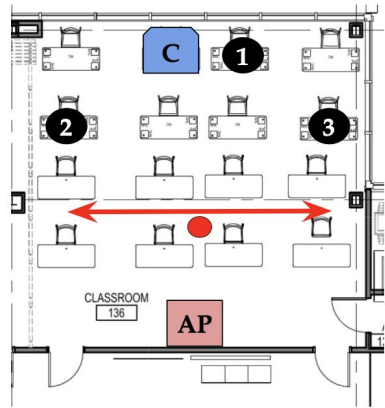
Emerging New Markets

New Market: 802.11bf
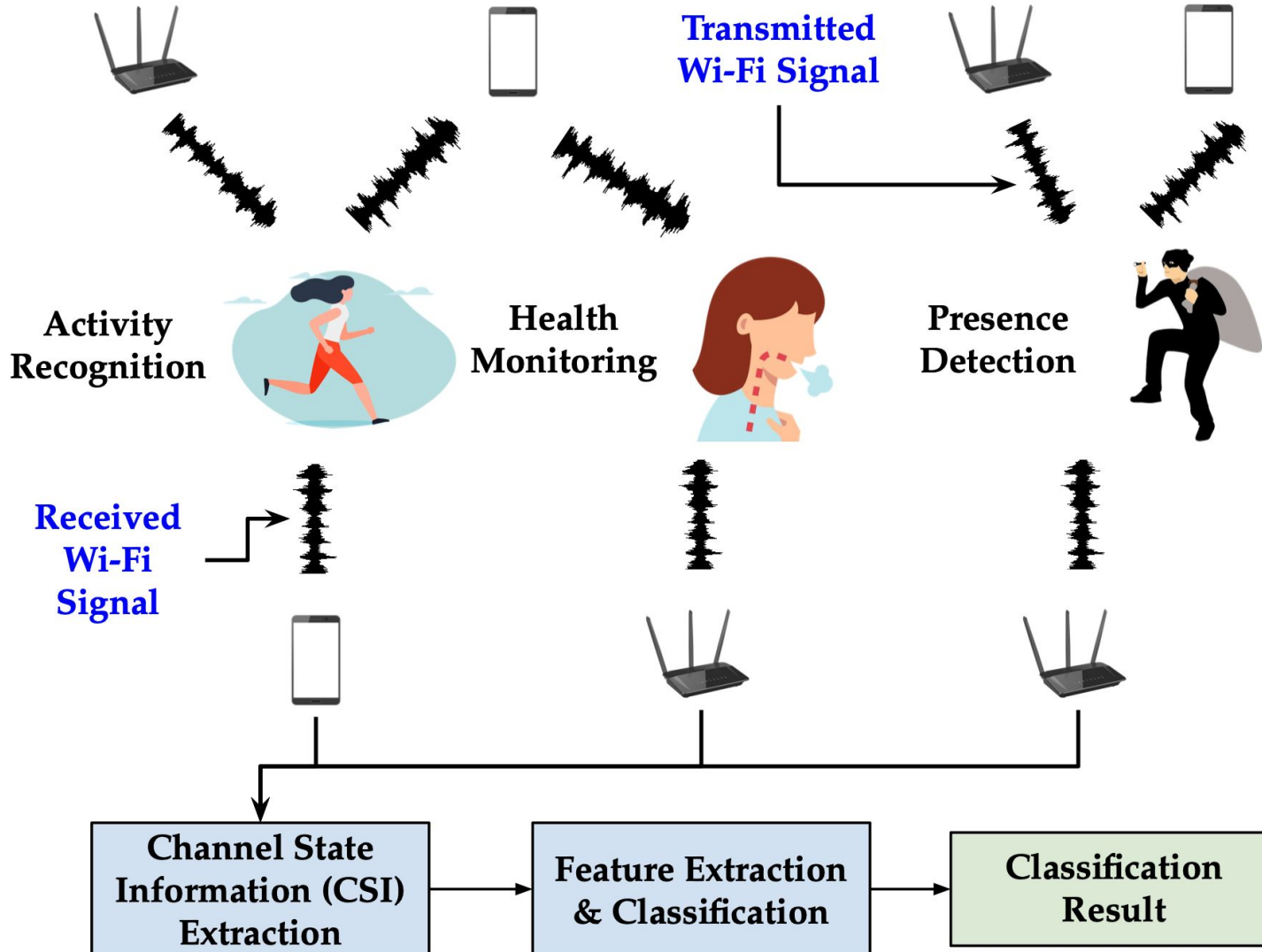
- The research community has worked on these topics for **~10 years**
- First "See Through Walls With Wi-Fi!" paper in **2013**
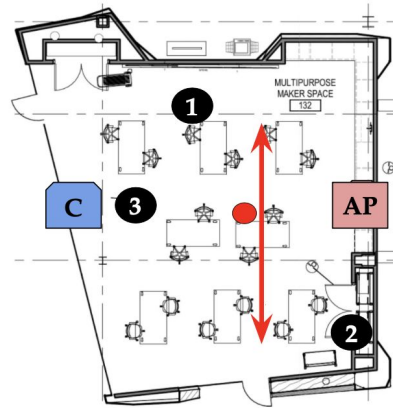- Extreme commercial potential, that's why **802.11bf** was created

Problems: Generalization, Robustness
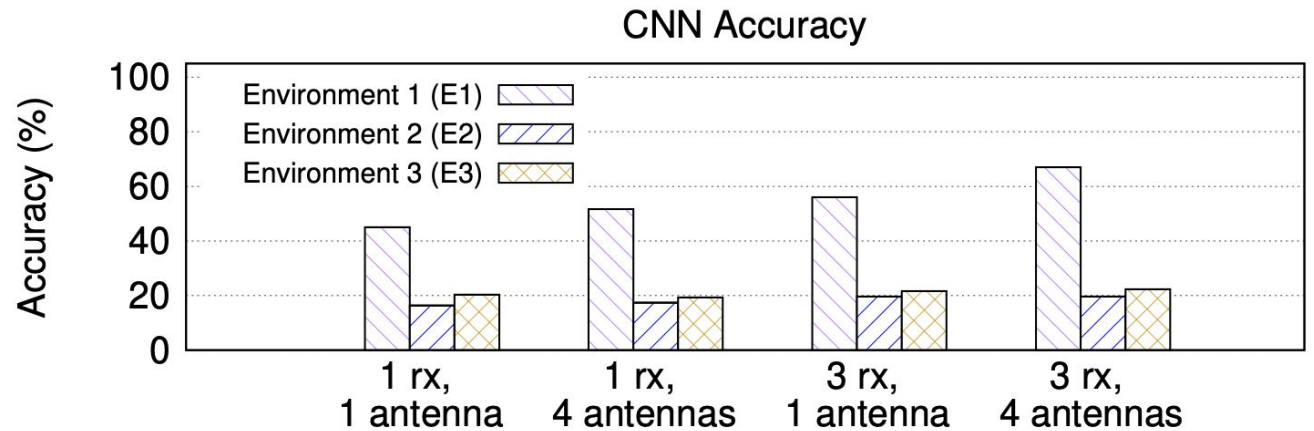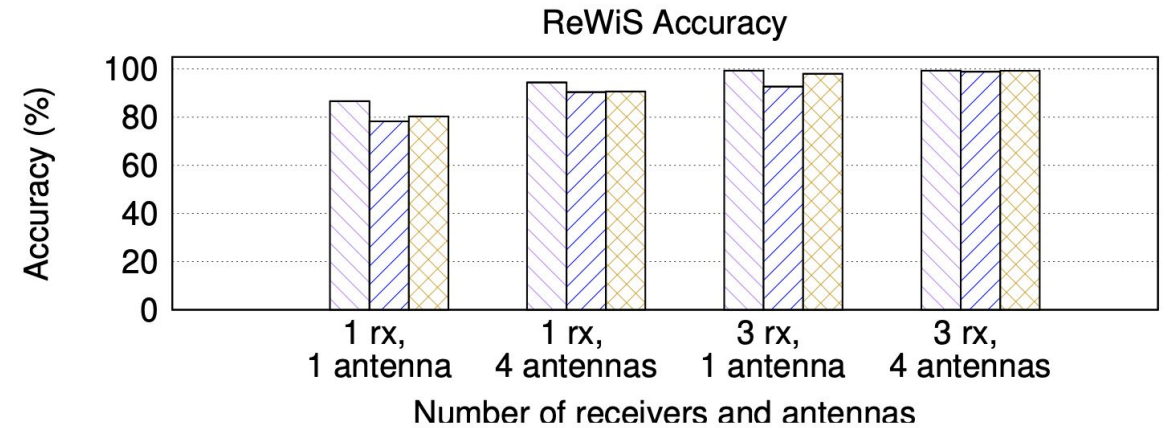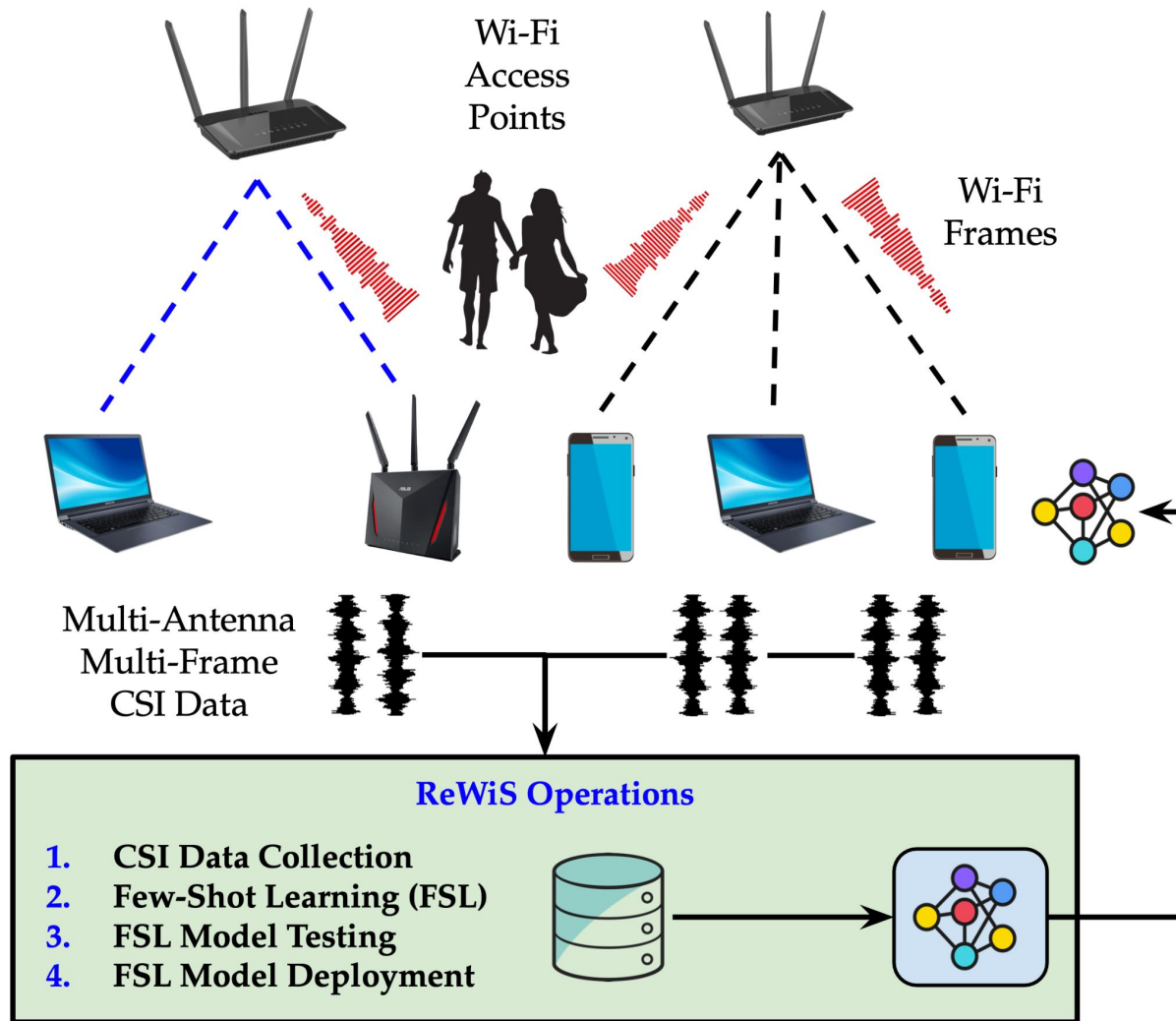
Environment 1 (E1)

Environment 2 (E2)

Environment 3 (E3)

1 — CSI Receiver (C)

AP — Access Point (AP)

C — Client (C)

↔ — Walking Pattern

● — In-Place Activity

CNN Accuracy

- Trained and tested in different environments
- Performance **does not generalize** to different environments
- Clients may not buy the product if it's a **one-trick pony**

Better Performance Through Cooperation

Wi-Fi Access Points

Wi-Fi Frames

Multi-Antenna Multi-Frame CSI Data

ReWiS Operations

1. CSI Data Collection
2. Few-Shot Learning (FSL)
3. FSL Model Testing
4. FSL Model Deployment

ReWiS Accuracy

Accuracy (%)

1 rx, 1 antenna

1 rx, 4 antennas

3 rx, 1 antenna

3 rx, 4 antennas

Number of receivers and antennas

- Through CSI fusion, we are able to generalize among different environments
- Ultimately, more sales because the product satisfies the customer better!

N. Bahadori, J. Ashdown, and F. Restuccia, "**ReWiS: Reliable Wi-Fi Sensing Through Few-Shot Multi-Antenna Multi-Receiver CSI Learning**," arXiv preprint arXiv:2201.00869, 2021.

Reality Check?

Today, routers need to be
hacked to extract CSI

CSI fusion techniques
are not supported by today's
802.11 standards

New companies that can be centered
around CSI sensing are **hindered**

New Market: AI-Driven Wi-Fi Offloading

802.11 Network

Cellular Network
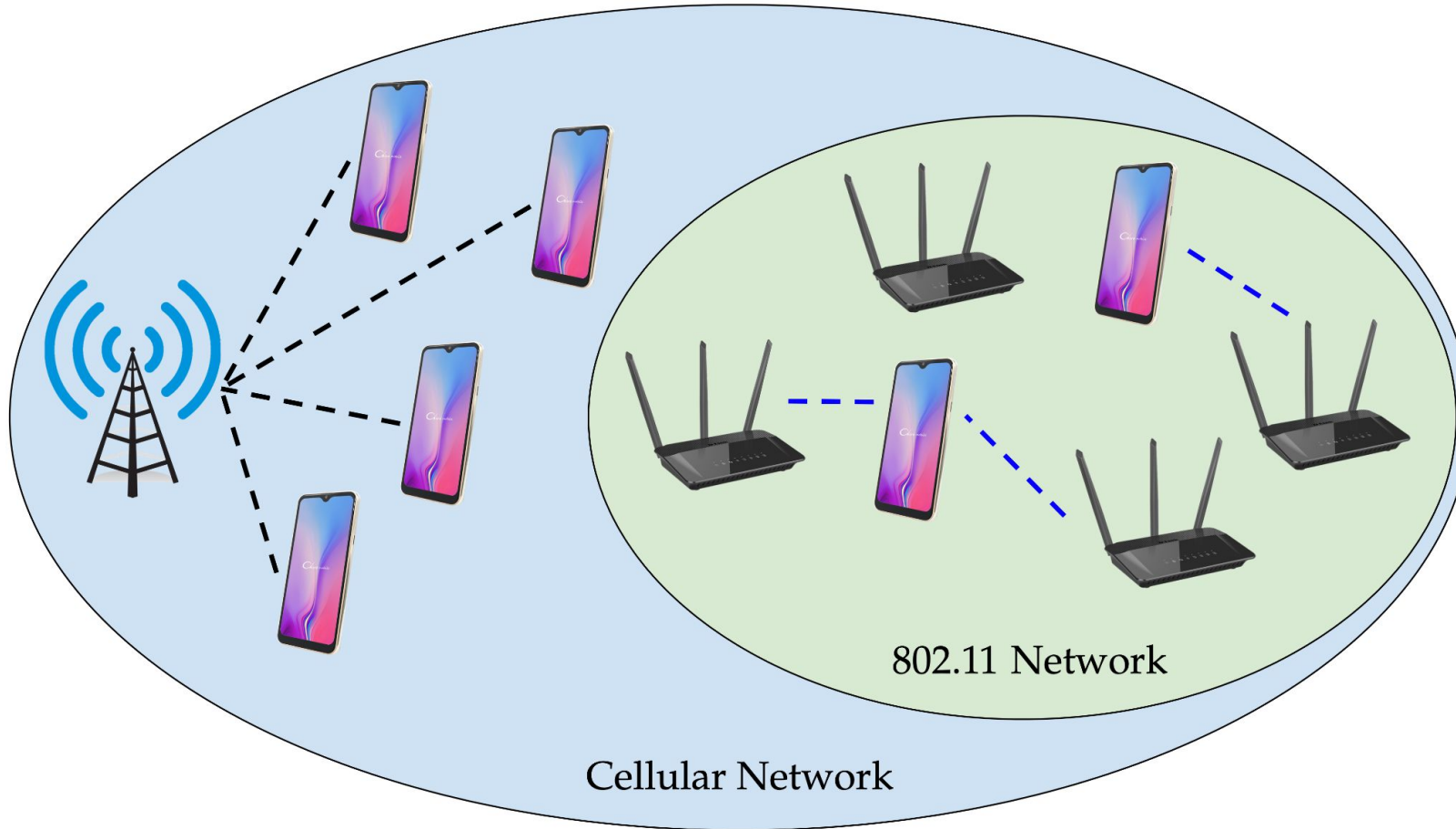
- The percentage of traffic offloaded to Wi-Fi will be **59%** in 2022

- 5G will offload a whopping **71%** of its traffic to Wi-Fi by 2022

- Reduces **costs** for providers, and ultimately, for customers

- Improves service, so more **customer experience** and less **churning**

Claus Hetting, Cisco VNI predicts bright future for Wi-Fi,
https://wifinowglobal.com/news-and-blog/new-cisco-vni-numbers-predict-bright-future-for-wi-fi-towards-2022/

# New Market: AI-Driven Wi-Fi Offloading

- **Exciting business opportunity**
  - Much cheaper for MNOs than deploying femtocells
  - Wi-Fi APs are ubiquitous in indoor settings
  - Networking-as-a-Service (NaaS)

- **Killer use cases:**
  - Shopping Malls
 - Stadiums
  - Concerts
  - ...
  - Crowded Places

Problem: Wi-Fi at Scale

- **Wi-Fi is not made for many users**
  - DL MU-MIMO is limited to **8** users in 802.11ax, **4** is 802.11ac
  - Maximum of **4** SS/user in 802.11ax, **2** SS/user in 802.11ac

- **Not scalable for these applications!**
  - More antennas, more BW is **not** the solution!
  - We cannot transform an **AP in a femtocell!**
  - We need **cost-effective** solutions

Solution: Cooperative AI-Driven Wi-Fi Offloading
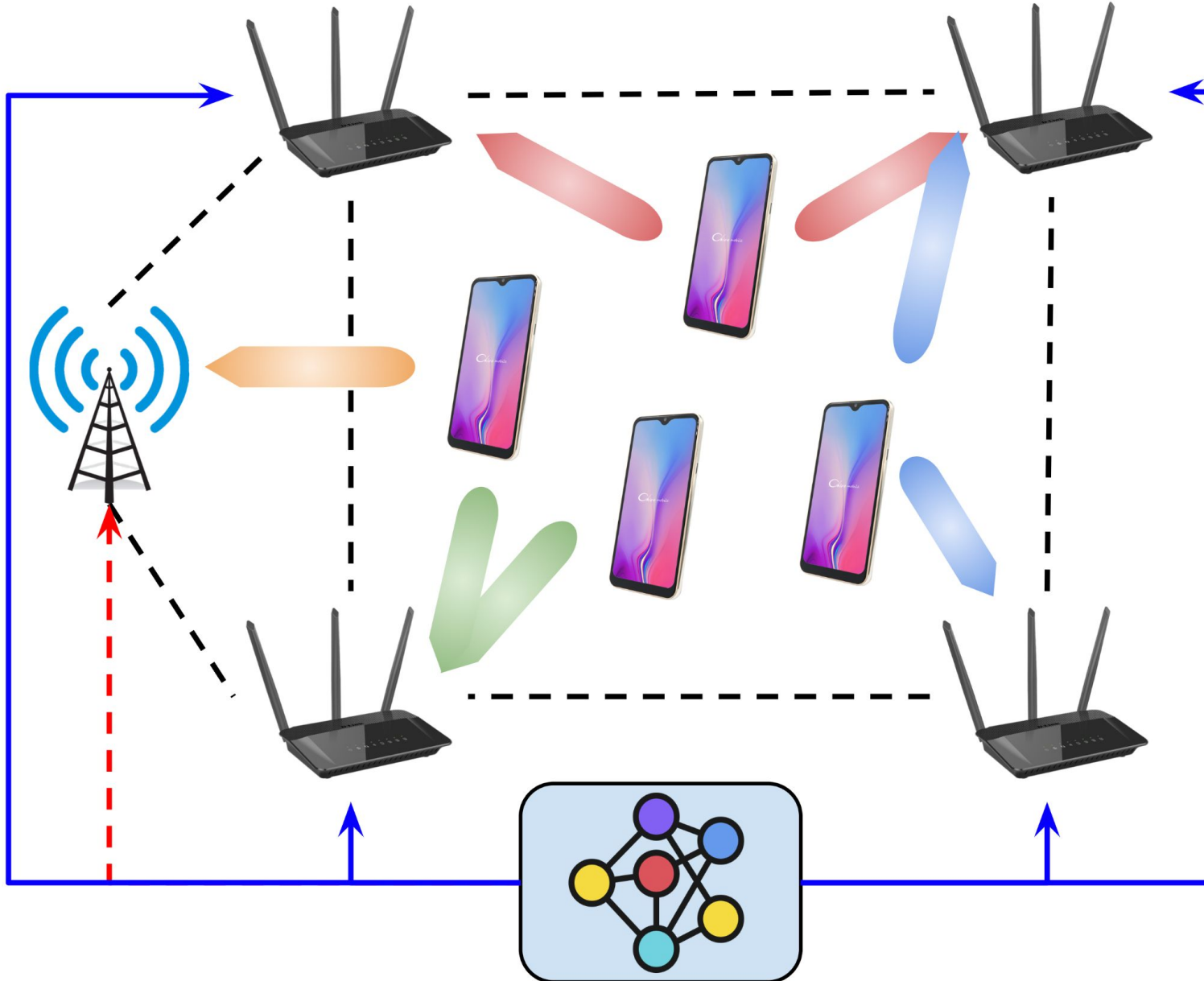
- Cheaper APs, but smarter (AI) and cooperative!
- Target: deploy more APs, bring complexity (and costs down)
- Sharing **spectrum** and network **information** with 5G networks

Spectrum Sharing with 5G O-RAN
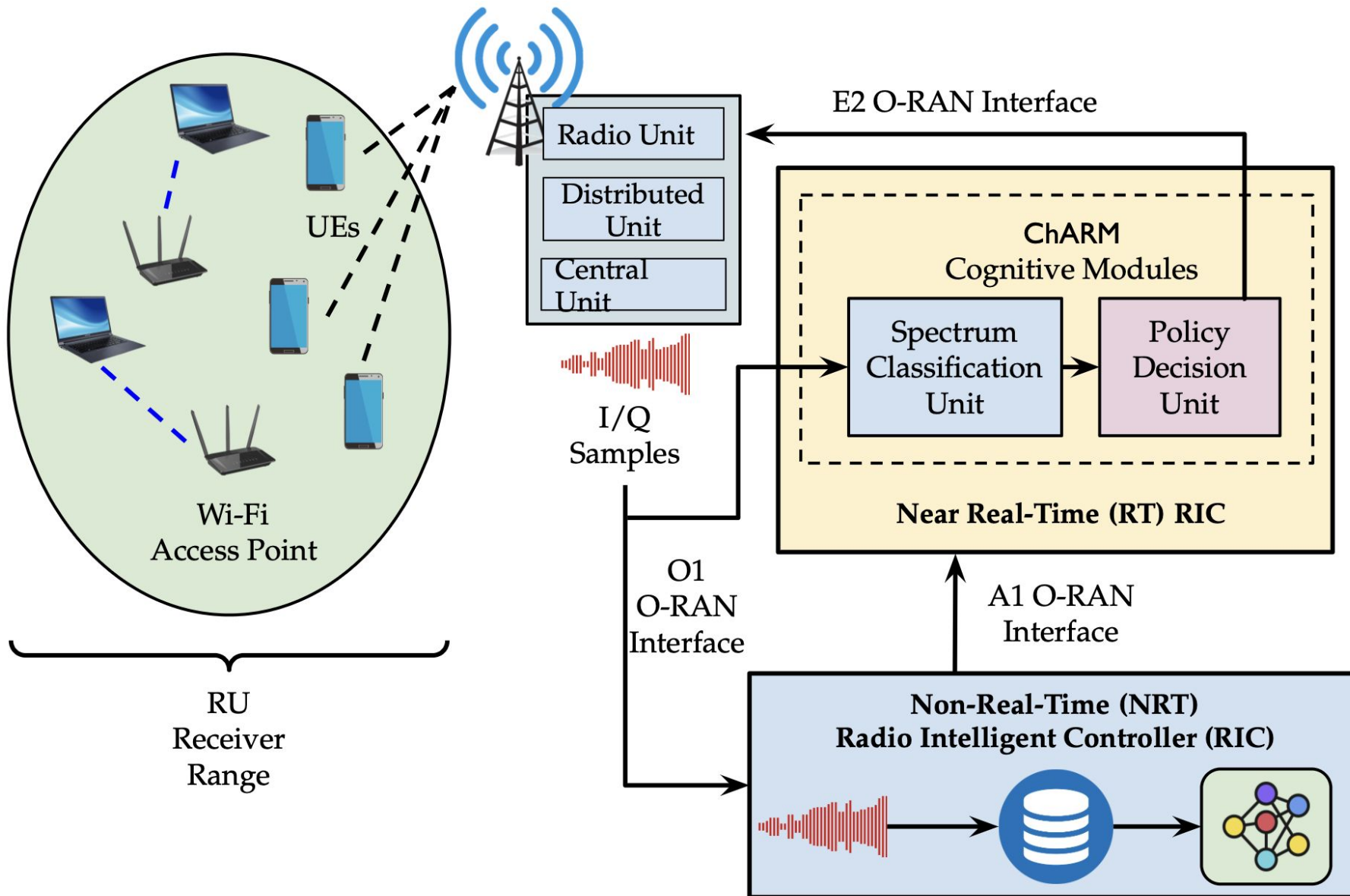
- **Software-based control achieves better spectrum utilization with less costs**

802 networks should adopt open, softwarized, AI-driven strategies to remain competitive

802 networks should learn to coexist with other technologies and embed AI by design into their architecture
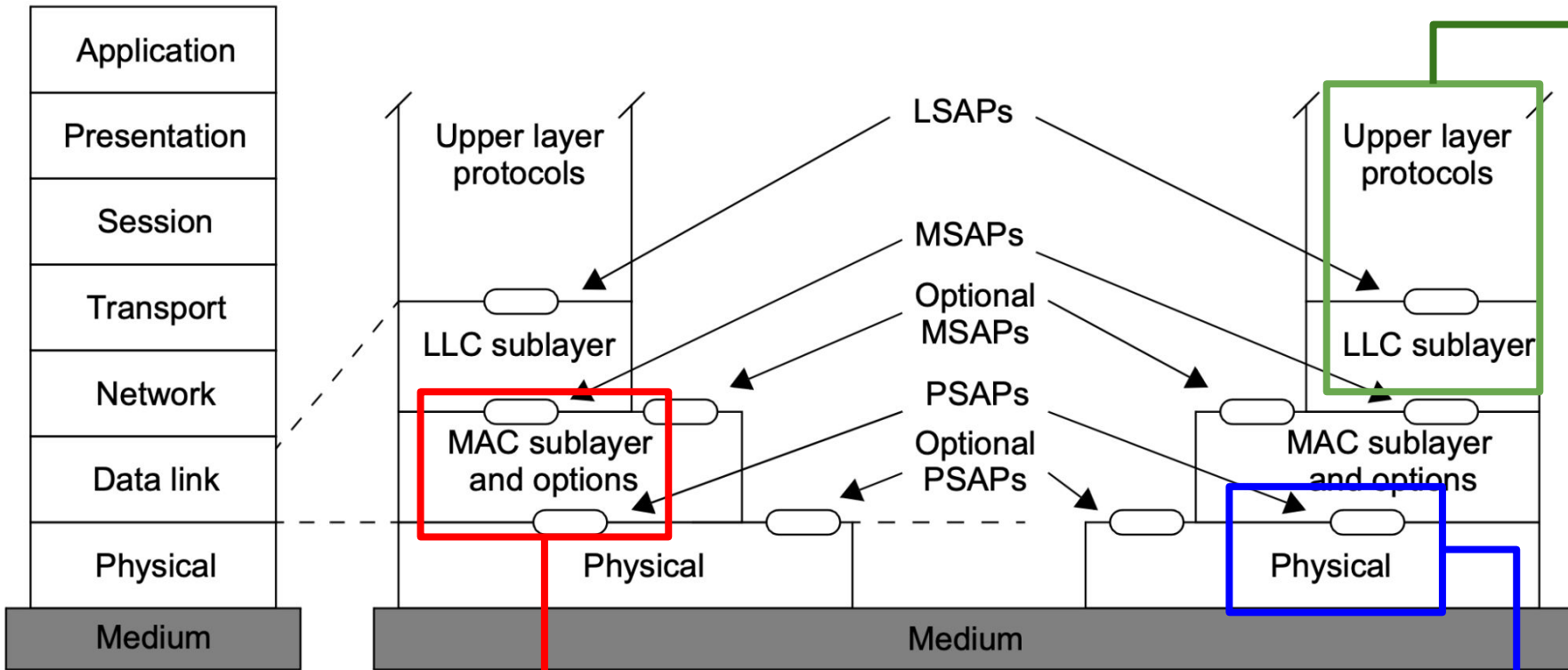
How can the 802 RM evolve?

Figure 3—IEEE 802 RM for end stations

Modules and Interfaces

- **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)

- **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)

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Thanks!
Questions?