

# Making the Case for Open, Softwarized, Data-Driven 802.11 Networks

Date: 2022-4-06

Authors:

<b>Name</b>	<b>Affiliations</b>	<b>Address</b>	<b>Phone</b>	<b>email</b>
Francesco Restuccia	Northeastern University, WIOT Institute	360 Huntington Ave, Boston, MA 02215 USA	617-373-3655	frestuc@northeastern.edu

# **What is the current threat**

**Risk of doing things as done now**

**How a softwarized, data-driven 802.11 architecture  
may drive costs down**

# Emerging new markets

**Enhancement of existing 802.11 business models**

**Creation of new 802.11 business opportunities**

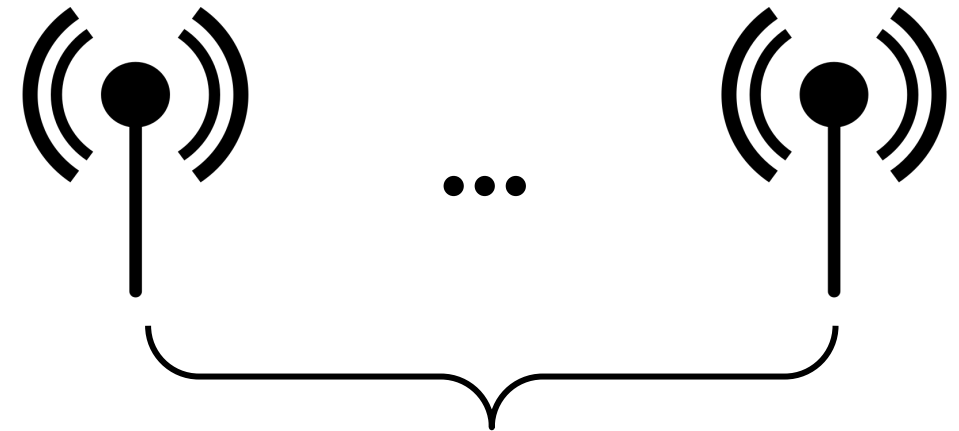
# What is the current threat?

# Strategy to improve 802.11 routers?

- Increase Bandwidth (2x)
- Increase Spatial Streams (2x)

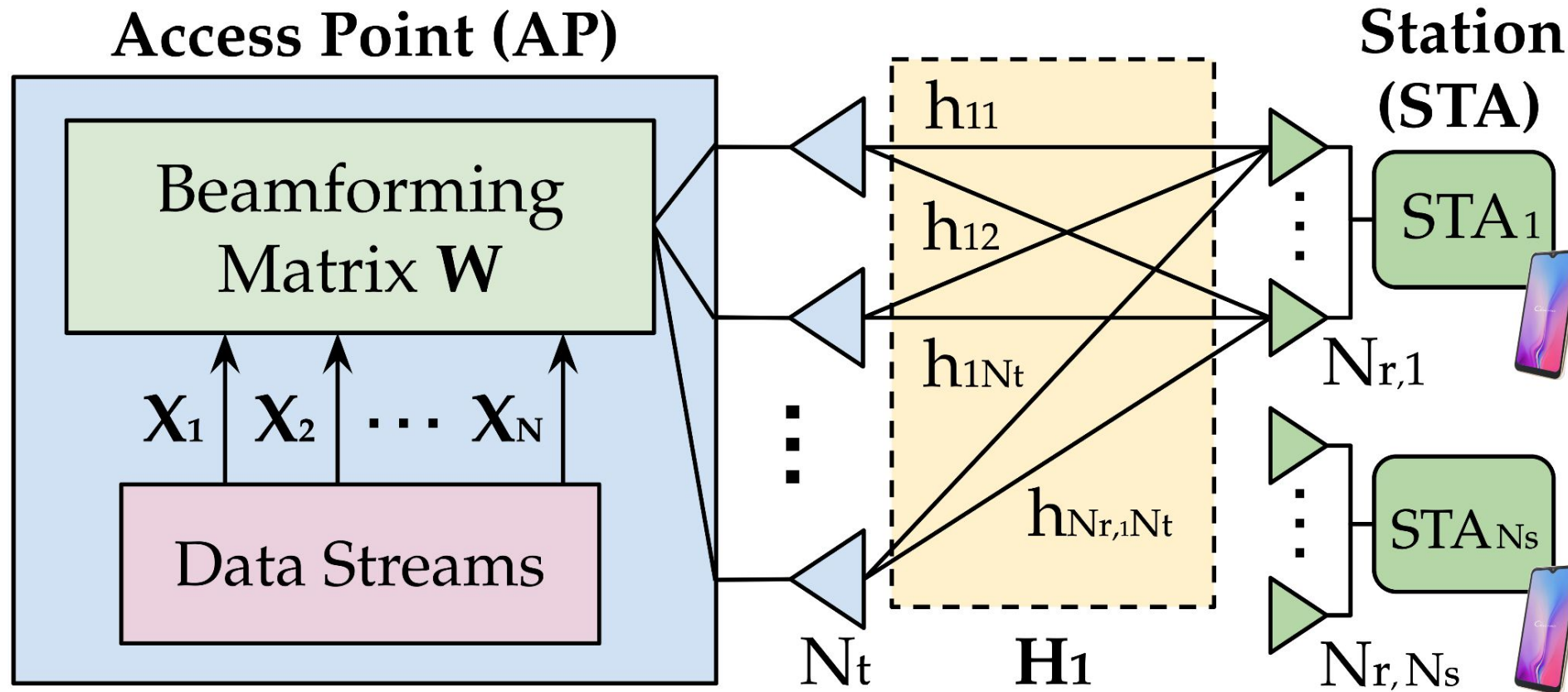
160 MHz  
(802.11ax)

320 MHz  
(802.11be)




- For better performance? Is it really needed?
- No 802.11ac routers that do 8x8 MIMO! Why?

## Complexity of MIMO in Wi-Fi Systems



8 x 8 @ 160 MHz, BM report is (486 subcarriers x 56 angles/subcarrier x 16 bits/angle) ~ **54.43 KB**

If BM reports are sent back every 10 ms, the airtime overhead is **435,456 / 0.01 ~ 43.55 Mbit/s**

- **Increasing complexity**
  - **Makes cost go UP!**
  - **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**
- 
- COST**

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**



# What's going on in the 5G/Cellular Community?



TSG SA priorities\*

SA2 led - System Architecture and Services

- XR (Extended Reality) & media services
- System Support for AI/ML-based Services
- Enablers for Network Automation for 5G Phase 3
- Enh. support of Non-Public Networks Phase 2
- Network Slicing Phase 3
- 5GC LoCation Services Phase 3
- 5G multicast-broadcast services Phase 2
- Satellite access Phase 2
- 5G System with Satellite Backhaul
- 5G Timing Resiliency and TSC & URLLC enh.
- Evolution of IMS multimedia telephony service
- Personal IoT Networks
- Vehicle Mounted Relays

SA3 led - Security and Privacy

- Privacy of identifiers over radio access
- SECAM and SCAS for 3GPP virtualized network products and Management Function (MnF)
- Mission critical security enhancements Phase 3
- Security and privacy aspects of RAN & SA features

SA4 led - Multimedia Codecs, Systems and Services

Systems & Media Architecture:

- 5G Media, Service Enablers
- Split-Rendering
- 5G AR Experiences Architecture

Media:

- Video codec for 5G
- Media Capabilities for Augmented Reality, Glasses

- AI / ML Study

Real-time Communications:

- XR conversational services
- WebRTC-based services and collaboration models

Immersive Voice & Audio:

- EVS Codec Extension for Immersive Voice and Audio Services (IVAS\_Codec)
- Terminal Audio quality performance and Test methods for Immersive Audio Services (ATIAS)

Streaming & Broadcast services:

- 5GMS Enh. (Network slicing, Low latency, Background Traffic, 5GMS Uplink)
- Further MBS Enh. (Free to air, Hybrid unicast/broadcast)

\*These are preliminary lists (As at SA#94-e)

Release 18

- Access Traffic Steering, Switching & Splitting support in the 5G system architecture Phase 3
- Proximity-based Services in 5GS Phase 2
- UPF enh. for Exposure & SBA
- Ranging based services & sidelink positioning
- Generic group management, exposure & communication enh.
- 5G UE Policy Phase 2
- UAS, UAV & UAM Phase 2
- 5G AM Policy Phase 2
- RedCap Phase 2
- Support for 5WWC Phase 2
- System Enabler for Service Function Chaining
- Extensions to TSC Framework to support DetNet
- Seamless UE context recovery
- MPS when access to EPC/5GC is WLAN

SA5 led - Management, Orchestration and Charging

Operations, Administration, Maintenance and Provisioning (OAM&P):

- Intelligence and Automation: Self-Configuration of RAN NEs, Enh. autonomous network levels, Evaluation of autonomous network levels, Enh. intent driven management services for mobile networks, AI/ ML management, Enh. of the management aspects related to NWDAF

Management Architecture and Mechanisms: Network slicing provisioning rules, Enh. service based management architecture

- Support of New Services: Enh. Energy Efficiency for 5G Phase 2, New aspects of Energy Efficiency for 5G networks Phase 2, Enh. management of Non-Public Networks, Network and Service Operations for Energy Utilities, Key Quality Indicators(KQIs)for 5G service experience, Deterministic Communication Service Assurance

Charging:

- Charging Aspects for Enh. Support of Non-Public Networks

SA6 led - Application Enablement & Critical Communication Applications

Critical Communications:

- MCX Enhancements – MC over 5GS (5MBS, ProSe) Adhoc group comm., MCPTT Enh.
- Railways - Gateway UE, Interworking

Service Frameworks:

- Edge App Architecture Enh., SEAL Enh., Subscriber-Aware API (CAPIF Enh.)

Enablers for Vertical Applications:

- Fused location, Application Data Analytics, App Layer NW Slicing
- Enhancements to V2X, UAS application-enablement
- Future Factories, Personal IoT networks, Capability exposure for IoT platforms

See the 3GPP Work Plan for full details, as Release 18 develops: [www.3gpp.org/specifications/work-plan](http://www.3gpp.org/specifications/work-plan)

TSG RAN priorities\*

RAN1 led - Radio Layer 1 (Physical layer)

- AI/ML - Air Interface
- NR MIMO Evolution
- Evolution of duplex operation
- NR Sidelink Evolution
- Positioning Evolution
- RedCap Evolution
- Network energy savings
- Further UL coverage enhancement
- Smart Repeater
- DSS
- Low power WUS
- CA enhancements

RAN2 led - Radio layer 2 & layer 3 Radio Resource Control

- Mobility Enhancements
- Enhancements for XR
- Sidelink Relay Enhancements
- NTN (Non-Terrestrial Networks) evolution - NR
- NTN (Non-Terrestrial Networks) evolution - IoT
- UAV (Uncrewed Aerial Vehicle)
- Multiple SIM (MUSIM) Enhancements
- In-Device Co-existence (IDC) Enhancements
- Small data
- MBS

RAN3 led - UTRAN/E-UTRAN/NG-RAN architecture & related network interfaces

Additional topological improvements – IAB/VMR

- AI/ML for NG-RAN WI
- AI/ML for NG-RAN SI
- SON/MDT Enhancements

- QoE Enhancements
- Resiliency of gNB-CU-CP

RAN4 led - Radio Performance and Protocol Aspects

- RAN4-led spectrum items
- <5MHz in dedicated spectrum

Rel-18 Workplan for TSG CT

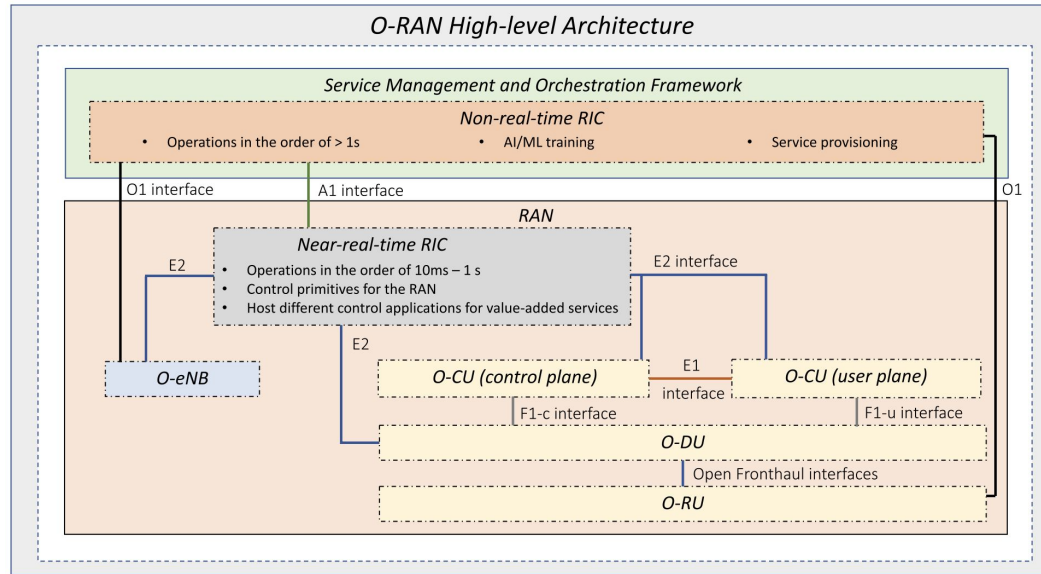
CT will work on Stage 3 completion and ASN.1 code and OpenAPI freeze of Rel-17 until June 2022 (TSG#96).  
Work Item discussion on Rel-18 Stage 2 / Stage 3 (under CT) from June 2022.

\*Source: RP-213697 (RAN#94-e)

(1) Decided to study “the benefits of augmenting the air-interface with features enabling improved support of AI/ML based algorithms for enhanced performance and/or reduced complexity/overhead”

<https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=3983>

# The Open RAN (O-RAN) Paradigm

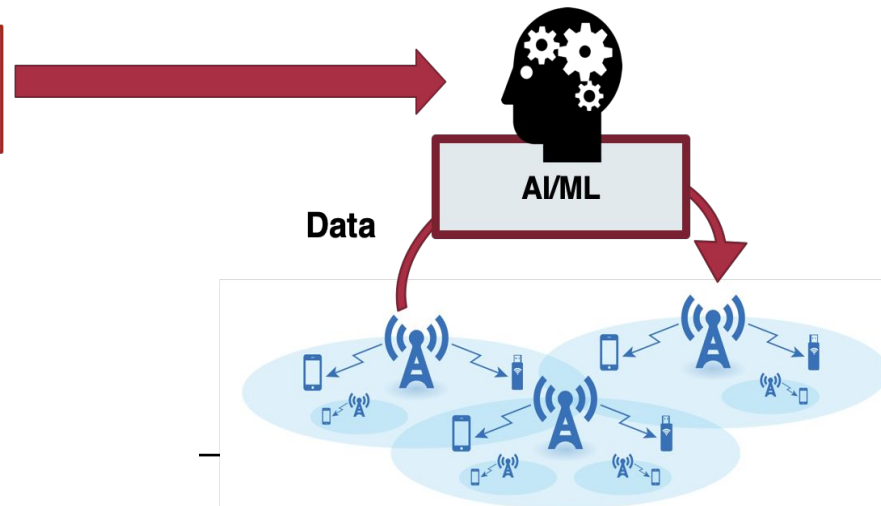


(1) Disaggregation of RAN **hardware** and **software**

(2) **RAN Intelligent Controller (RIC)** operating at different granularity levels

- Control is **hardware-** and **vendor-agnostic**, so software runs in any O-RAN compliant network
- Zero-touch AI-based control is **natively supported**,
  - best performance
  - self-adaptation

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



## **Advantages of Open, Virtualized Networks**

- 1. Interoperability reduces CAPEX (60%)**
- 2. Future-proof – no rip and replace infrastructure**
- 3. Easier maintenance results in reduced OPEX (65%)**
- 4. 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/>

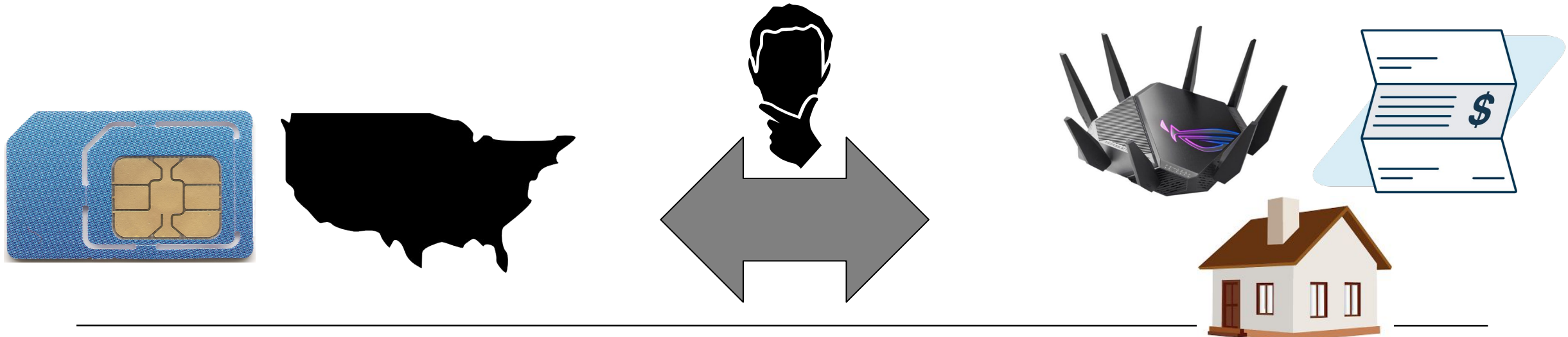
**Apply the Same Concepts to Wi-Fi?**

**Do more with less antennas and BW  
(SW vs HW), yet more devices (unlicensed  
bands!)**

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

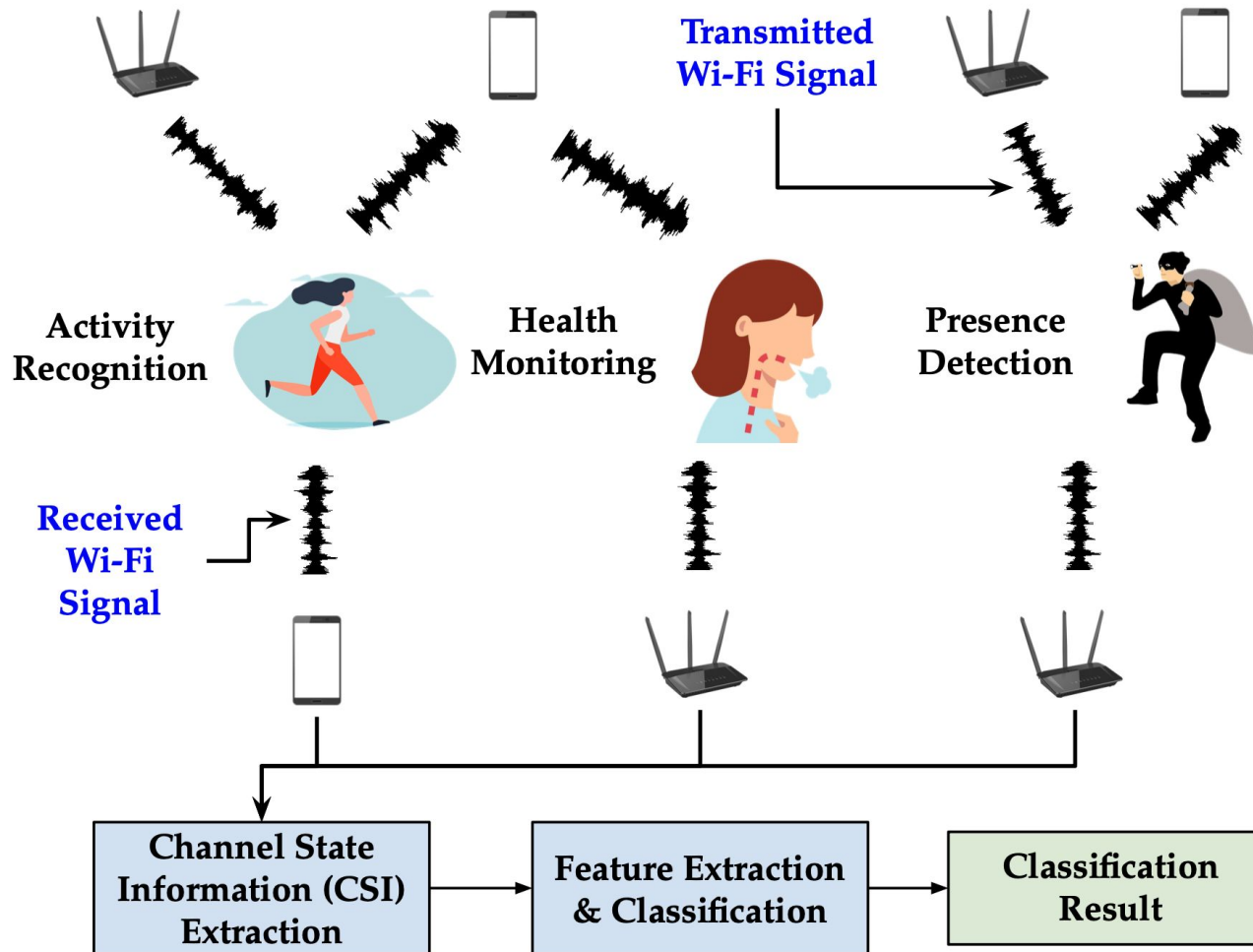
Apply the Same Concepts to Wi-Fi?

Good performance with **less costs!**  
(People will choose **802.11**  
and **not 5/6G networks**)



# Emerging New Markets

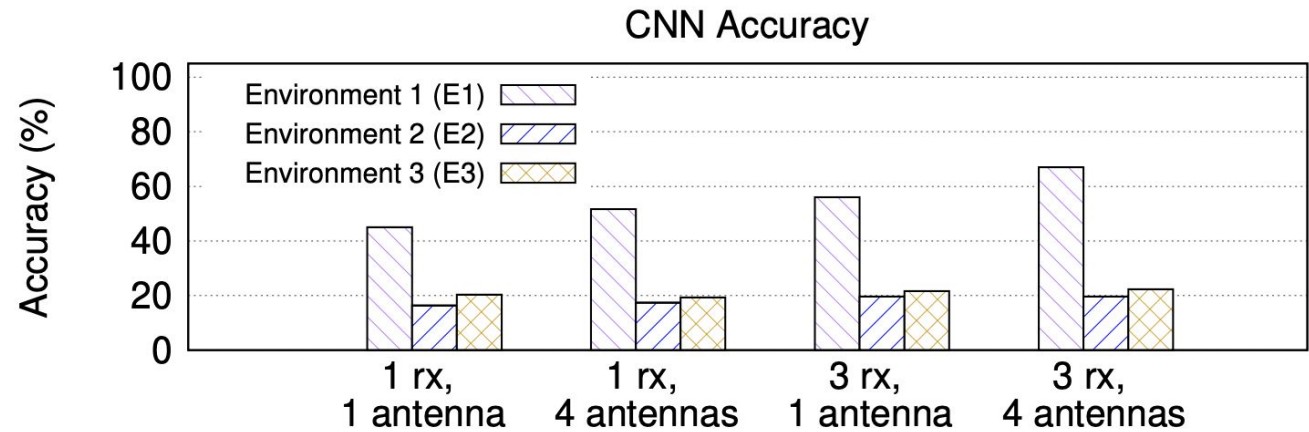
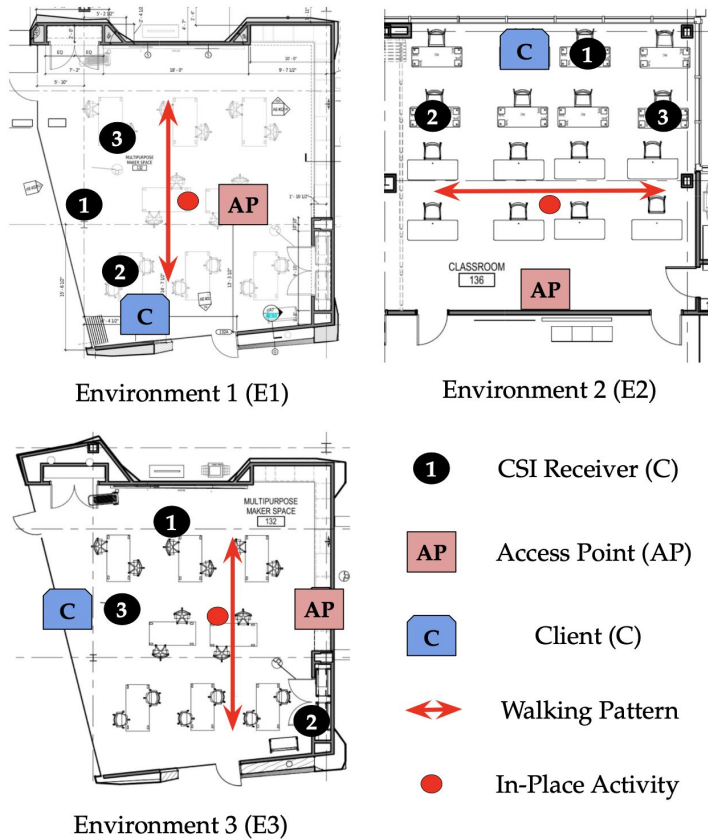
# New Market: 802.11bf



- **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**



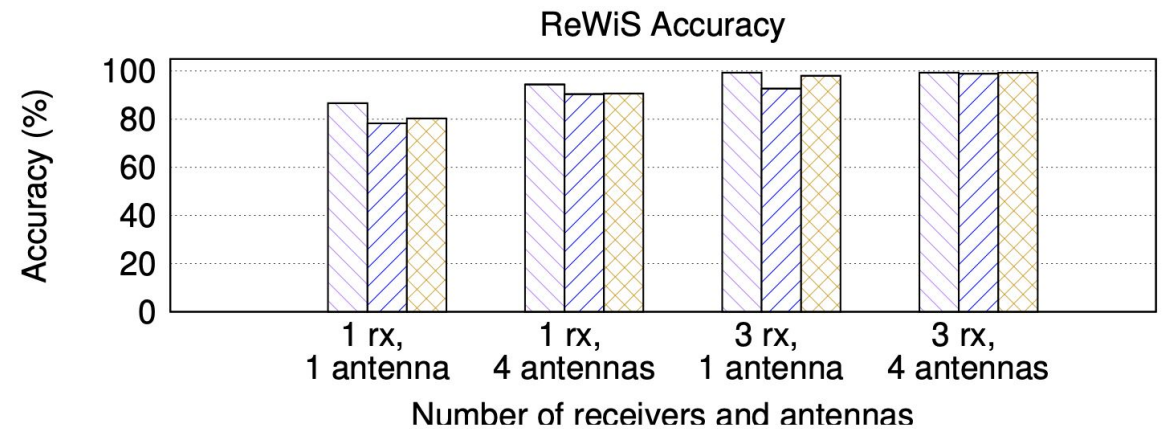
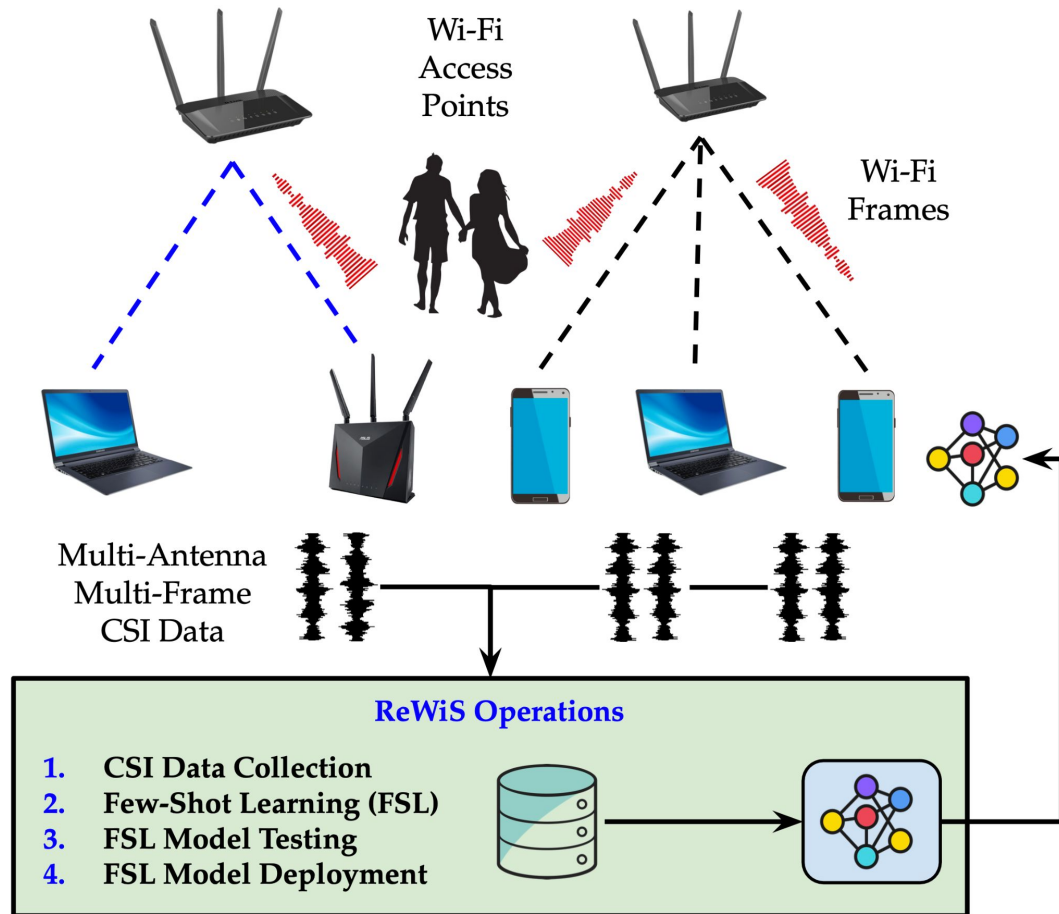
# Problems: Generalization, Robustness



- Trained and tested in different environments
- Performance does not generalize to different environments
- Clients may not like the product
- Some Wi-Fi sensing devices have been shown to experience problems in actual deployments [1]

[1] Christopher Null (TechHive). "Aura review: This home monitoring system is more trouble than it's worth." <https://www.techhive.com/article/583109/aura-review.html>, December 27, 2017.

# Better Performance Through Cooperation



- 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,**” to appear in **IEEE WOWMOM 2022**. Preprint available at <https://arxiv.org/abs/2201.00869>

# Reality: Today, it's **very hard** to extract CSI from routers

---

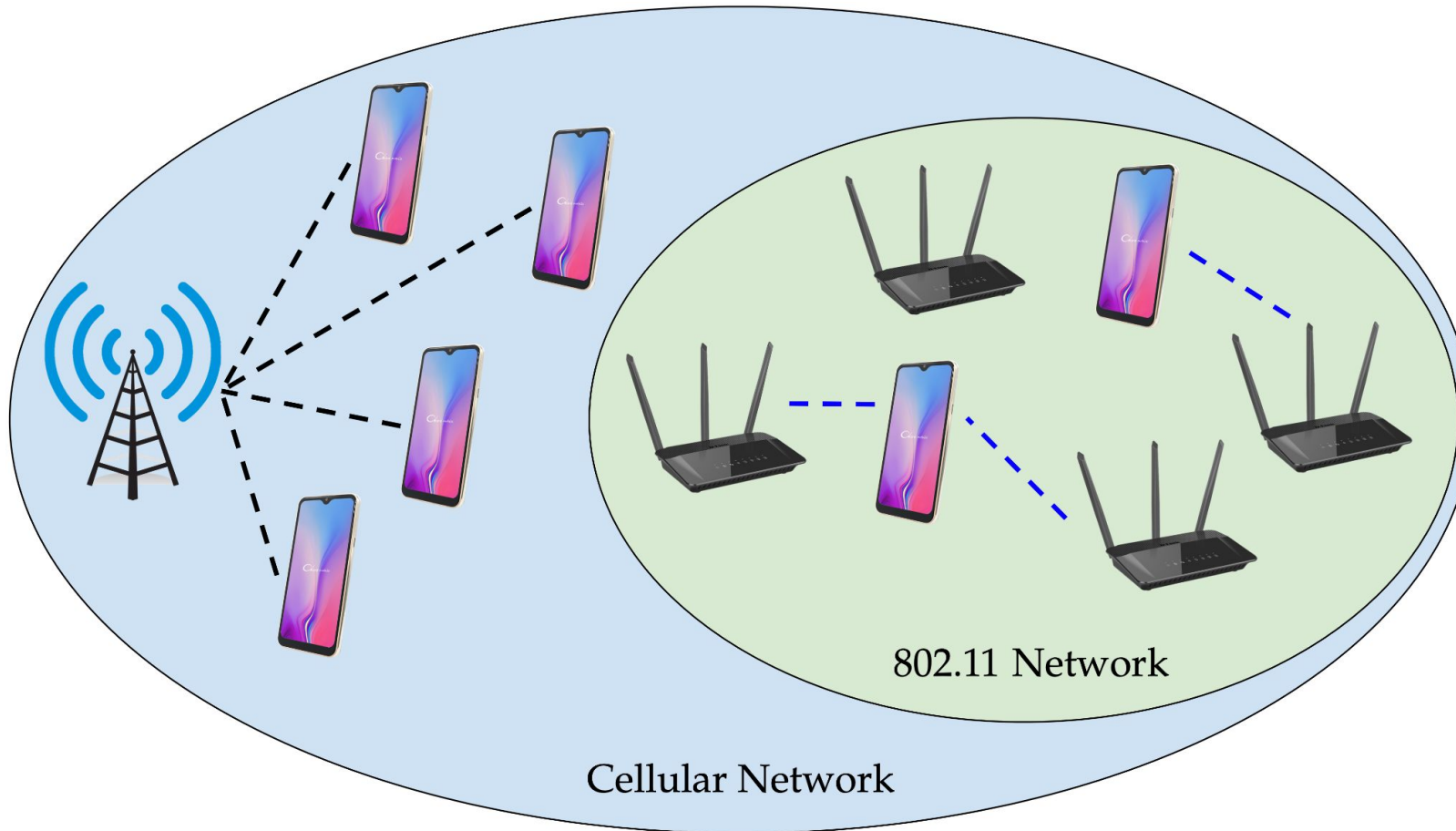
Tool	IEEE Std	Data points/CSI
CSI Tool [4]	802.11n	30
Atheros CSI Tool [8]	802.11n	56
Nexmon CSI [3]	802.11ac	up to 4096
AX-CSI [2]	802.11ax	up to 32768

---

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



- 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:**

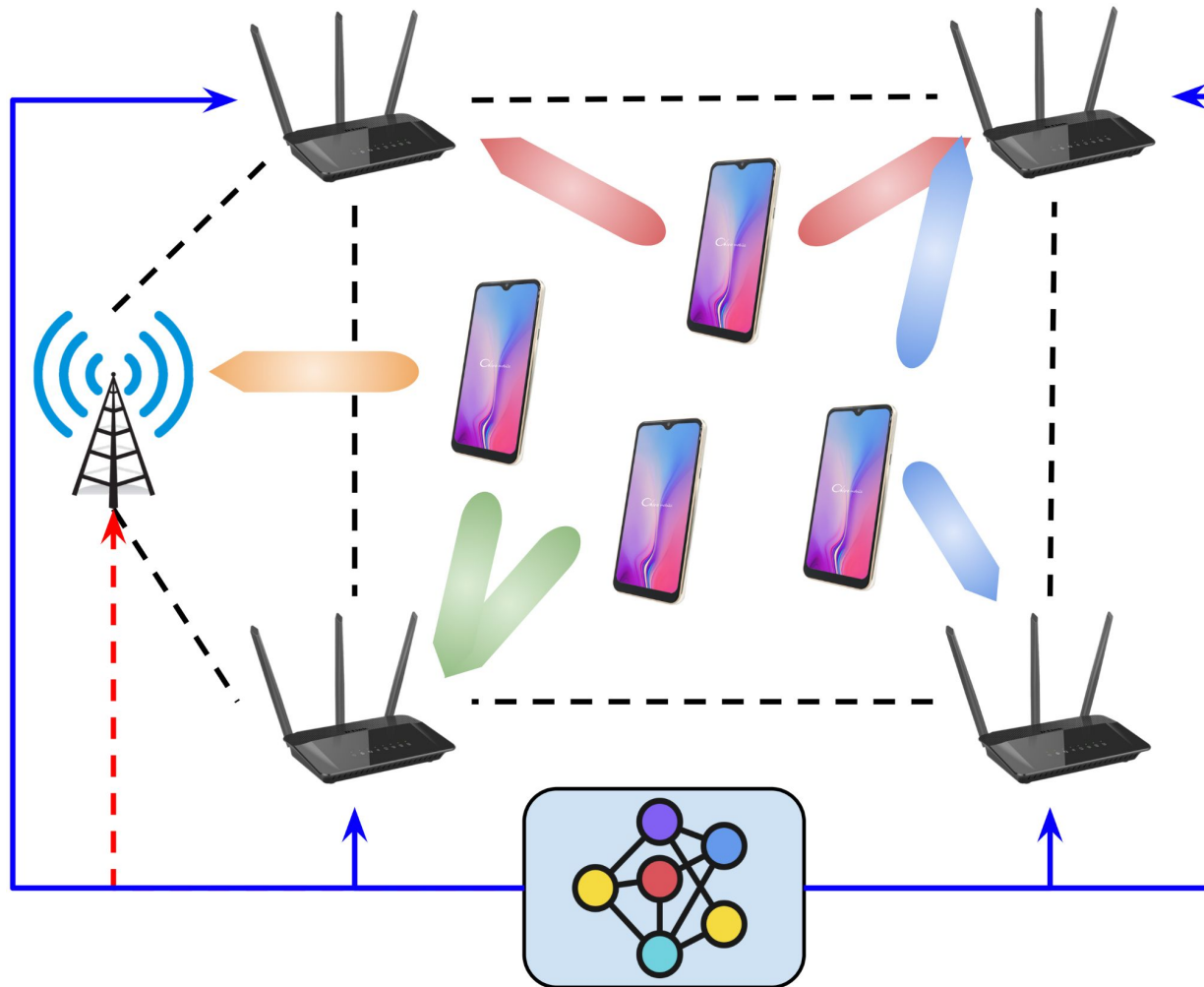
- Shopping Malls
- Stadiums
- Concerts
- ...
- Crowded Places



## 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** in 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



## To Summarize

**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?

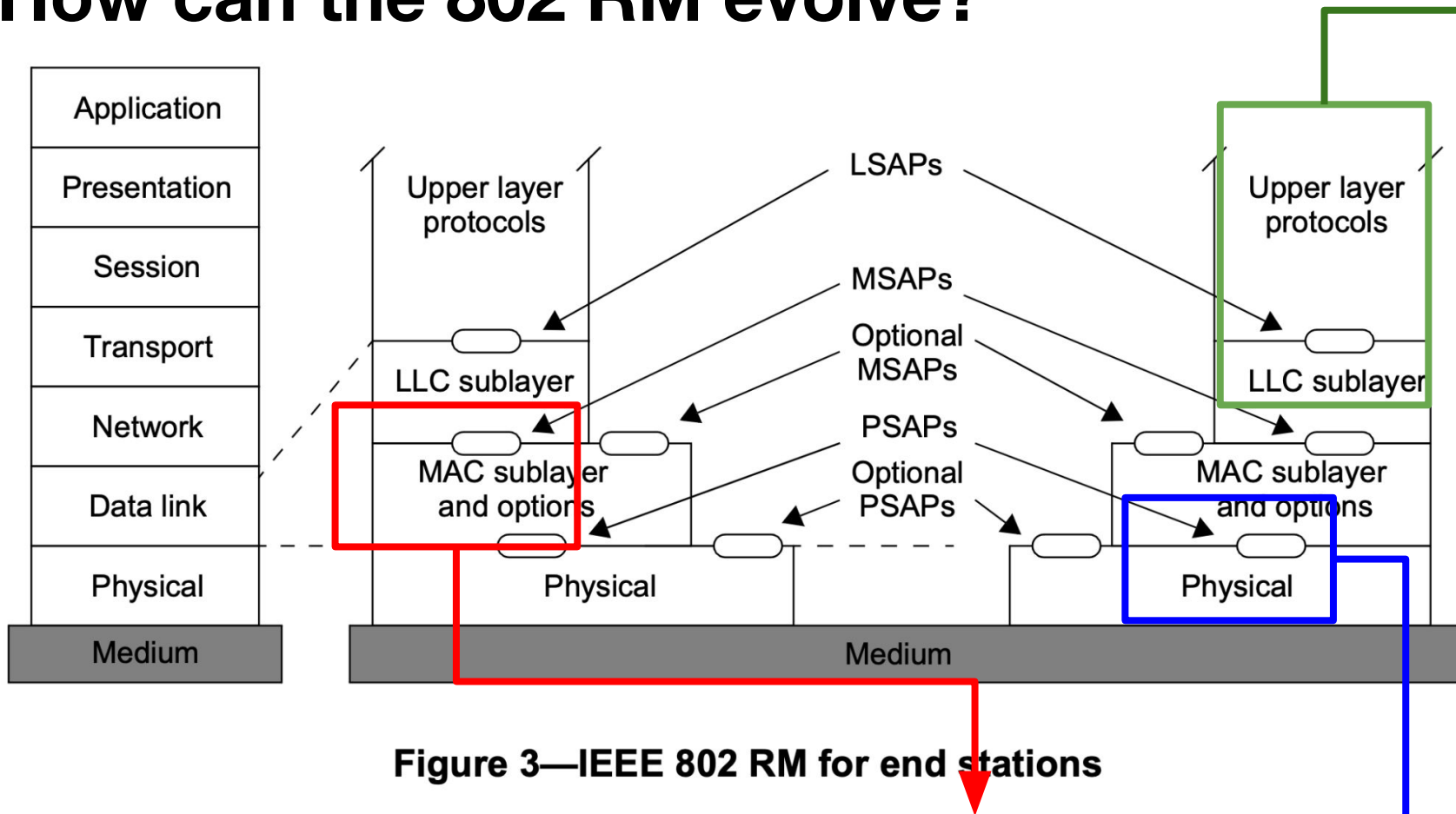


Figure 3—IEEE 802 RM for end stations

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

## Modules and Interfaces

- **Interfaces** for MAC control & monitoring

## Straw Poll

**"Do you support the creation of a TIG to:**

- a. describe use cases for AI/ML applicability in 802.11 systems
- b. investigate the technical feasibility of "features enabling support of AI/ML based algorithms in the 802.11 MAC/PHY"

**Thanks!**  
**Questions?**