CS/ECE 439: Wireless Networking

WiFi 7

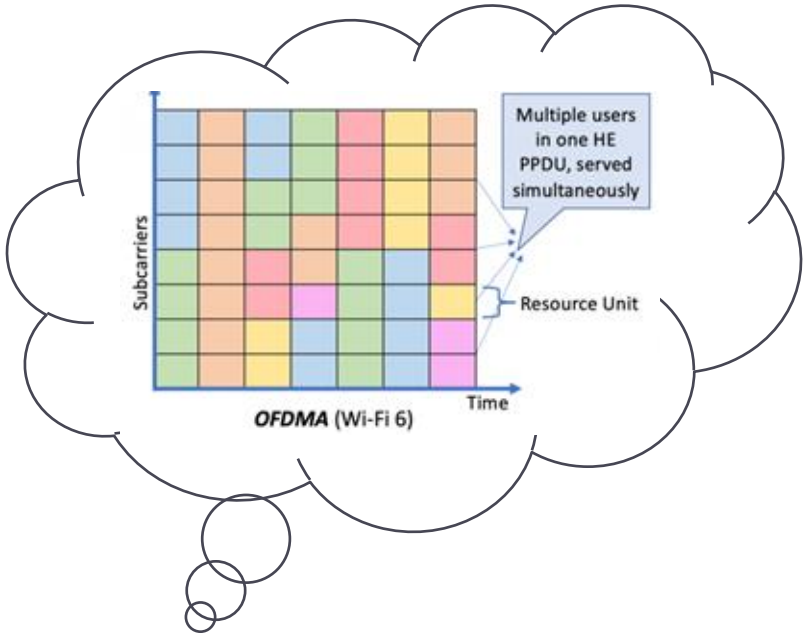
GRAINGER ENGINEERING

© CS 439 Staff, University of Illinois

COMPUTER SCIENCE

Wi-Fi 6/6E

- 3 bands
  - 2.4, 5, 6 GHz
- OFDMA
  - Router controls scheduling
- Channels
  - Split into Resource Units (RUs)



Improvement goals

- Better data rate?
  - More frequency bands
  - Wider channel width
  - Denser modulation
  - More spatial streams

Improvement goals

- Better data rate?
  - More frequency bands — Restricted by FCC!
  - Wider channel width — Large channels -> more BW!
  - Denser modulation — More bits per symbol
  - More spatial streams — More total capacity

Improvement goals

- Better channel utilization?
- Big improvements with WiFi 6 OFDMA, but can we do better?
  - What if a section if my channel is blocked?
  - Is channel still underutilized?

Improvement goals

- Better channel utilization?
- Big improvements with WiFi 6 OFDMA, but can we do better?
  - What if a section if my channel is blocked?
  - Is channel still underutilized?

Can we work around it?

If we are clever with RUs, what can we do?

WiFi 7 Features

- Multi-Link Operation (MLO)
- Multi-RU puncturing
- Multi-Resource Unit (multi-RU)
- General improvements
  - Wider channels
  - More MCS levels
  - More MIMO streams
  - etc.

Image: from a WiFi 7 card on Amazon

WiFi 7 Multi-Link Operation (MLO)

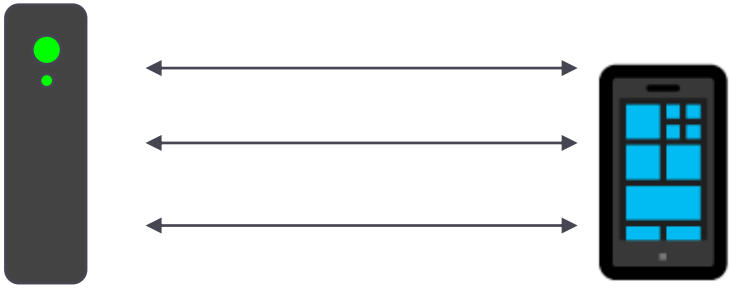
- Multiple links to communicate with a pair of devices
- Different configurations
- Capabilities vary from device to device

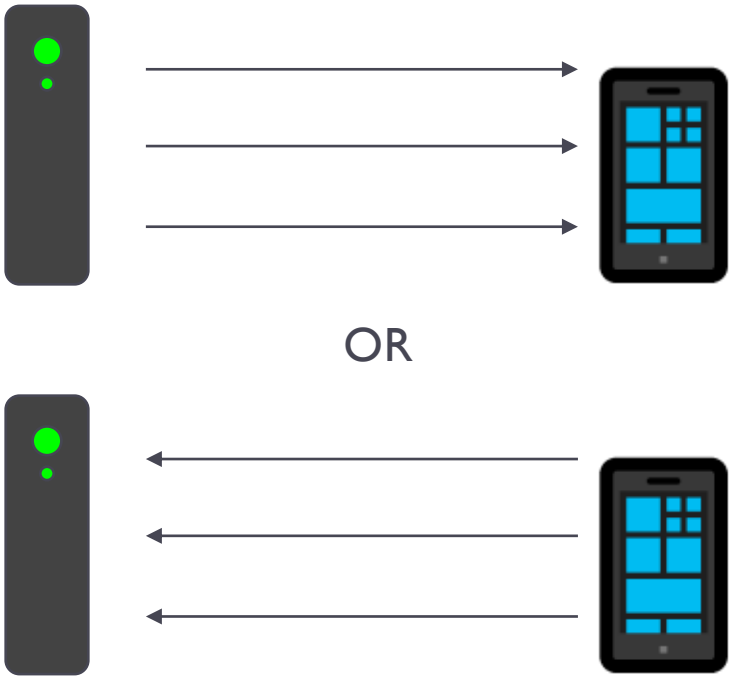
WiFi 7 Multi-Link Operation (MLO)

- Send more data
  - Simultaneously send on multiple links
- Simultaneous Tx/Rx
  - Send on one link, listen on another
- Pick band based on task
  - Demanding tasks get higher data rate?
- Pick band based on channel conditions
  - If one band is overloaded, use another
- Redundant transmission

MLO w/ multiple radios: Multi Link Multiple Radio (MLMR)

- STR: Simultaneous Tx & Rx
- NSTR: Non-Simultaneous Tx & Rx

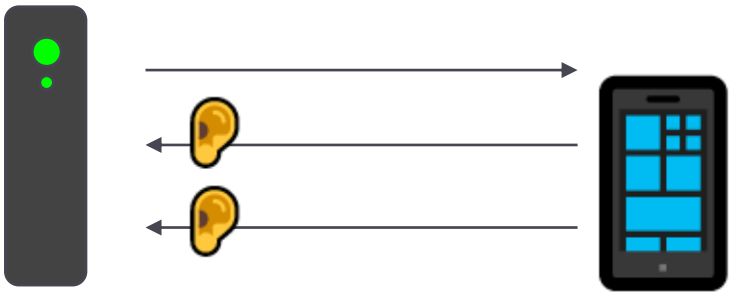




MLO w/ single radio - Multi Link Single Radio (MLSR)

- MLSR: Multi Link Single Radio
- E-MLSR: Extended MLSR

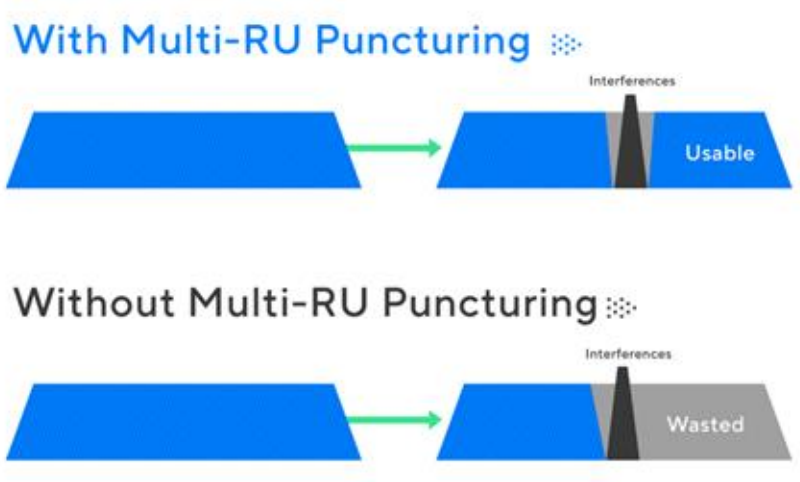
Tx or Rx on one link at a time



Tx on one link
Rx on (up to) two

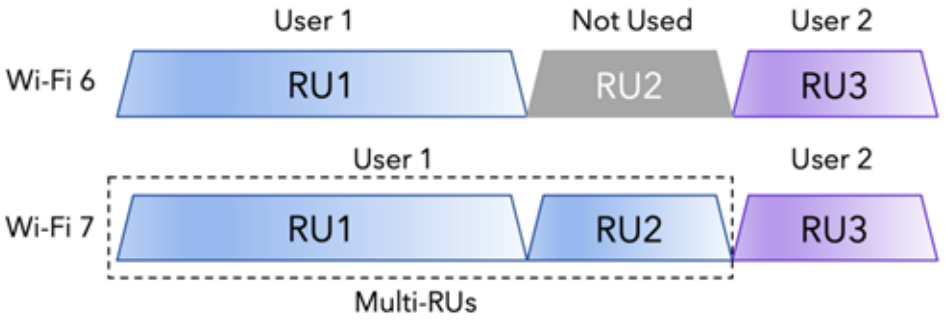
Preamble puncturing

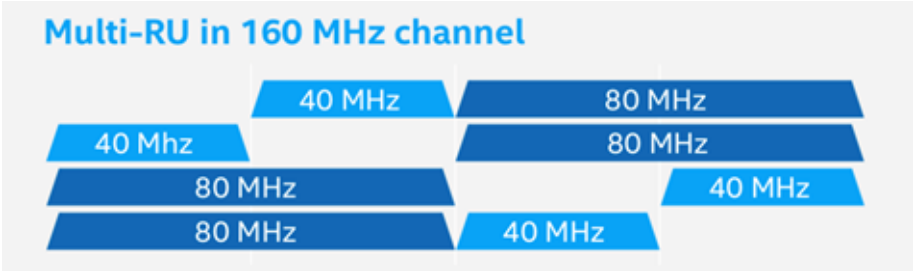
- "Snip out" sections of channel which are in use
  - For example, by radar
- Don't need perfectly contiguous channel
- However
  - Not supported for all channel sizes
  - May not be available on all bands
  - Only certain patterns required in WiFi 7



Multi-RU

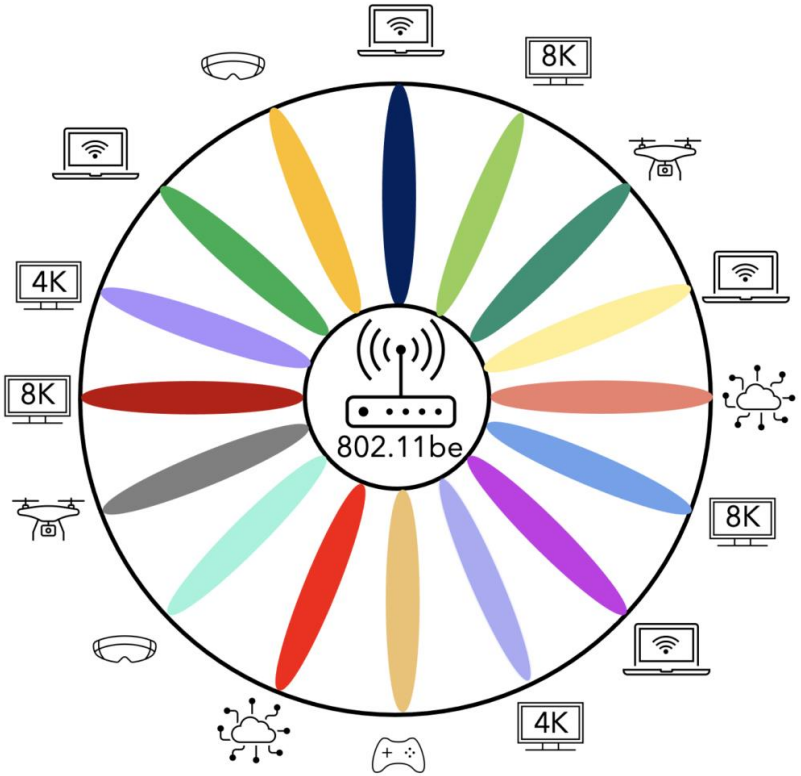
- Multiple RUs can be assigned to a single user
- Potential for greater data rate and channel utilization
- RU allocation scheme dependent on the number of users to handle, channel bandwidth, etc.





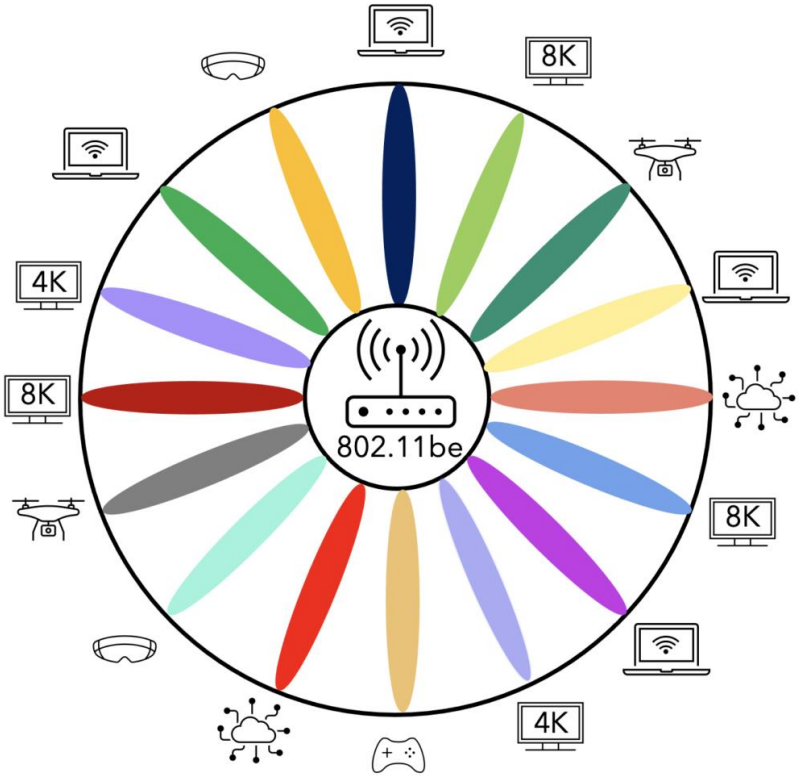
Spatial Streams

- WiFi 6 (802.11ax)
  - Max 8 spatial streams
- WiFi 7
  - Max 16 spatial streams
  - More streams = more simultaneous data paths between AP and client(s)
    - Directly boosts peak throughput
  - Combines with wider (320 MHz) channels and higher-order MIMO
    - Big potential throughput gains



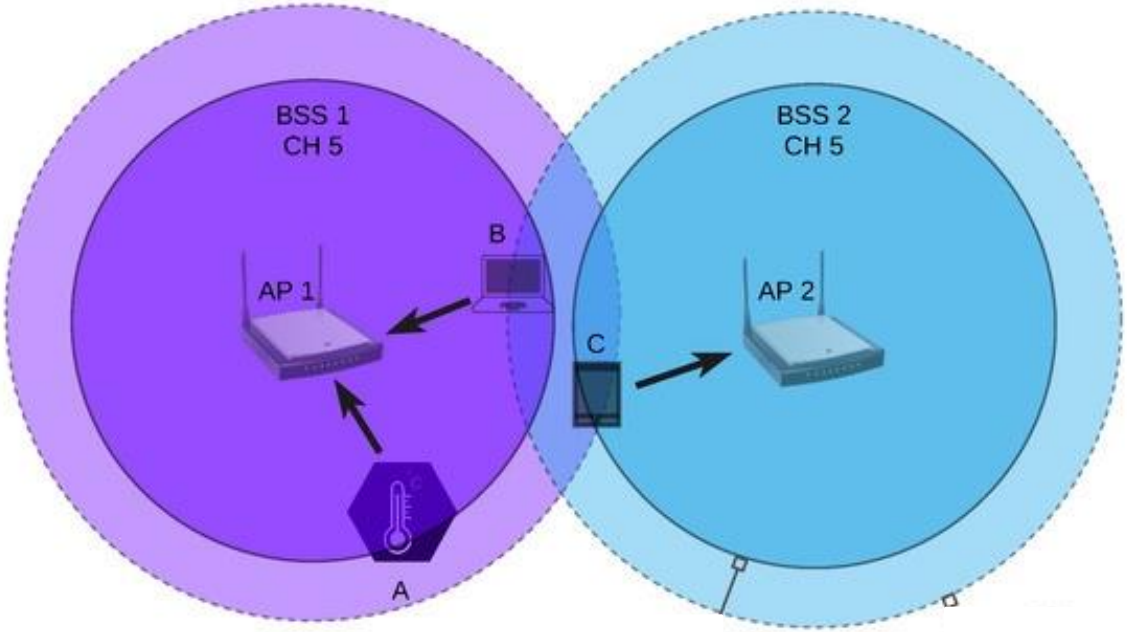
Spatial Streams

- Mostly AP-side
  - 16 streams requires 16 antennas at both ends
    - Realistic for an AP, not for a phone or laptop
- In practice, most of the benefit comes through MU-MIMO
  - AP splits its streams across several clients rather than one device using all 16



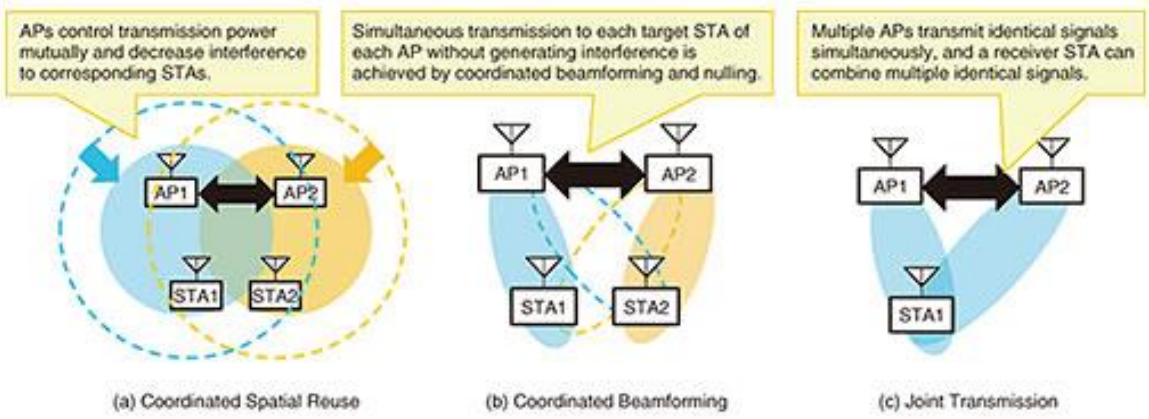
Multi-AP Coordination

- The old way
  - Neighboring APs just avoid each other's channel
  - Sense the channel is busy, back off



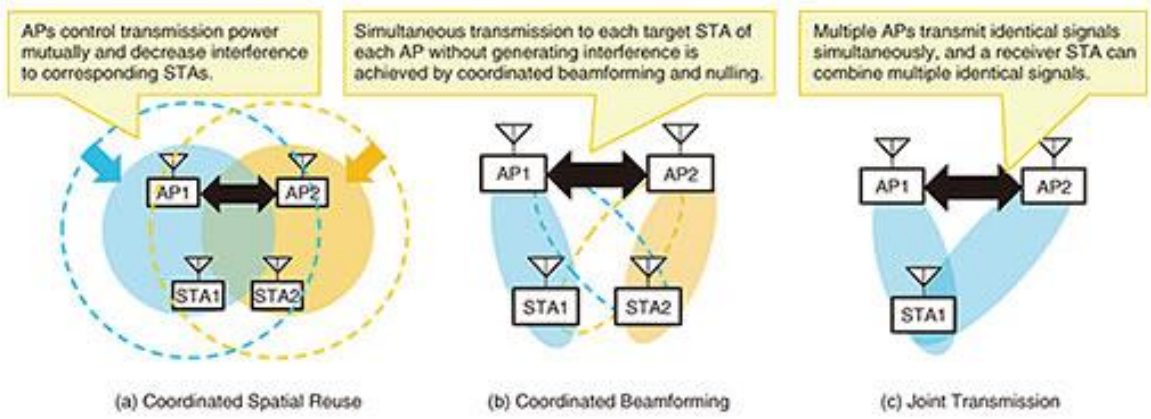
Multi-AP Coordination

- WiFi 7's plan (ultimately deferred to WiFi 8)
  - Neighboring APs coordinate directly
  - Coordinated Beamforming
    - Nearby APs steer their nulls toward each other's clients
    - Cuts interference instead of just avoiding it
  - Coordinated/Joint Transmission
    - Multiple APs jointly transmit to the same client
    - MIMO, but the antennas belong to different APs



Multi-AP Coordination

- Borrows directly from cellular's CoMP (Coordinated Multi-Point)
- Needs a low-latency backhaul link between APs
  - Not yet common in shipping hardware

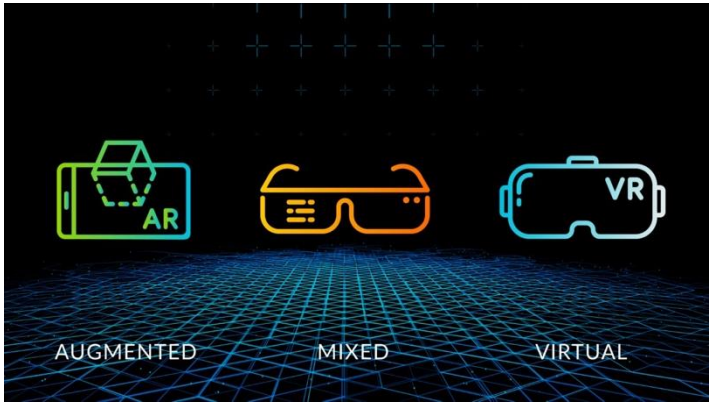


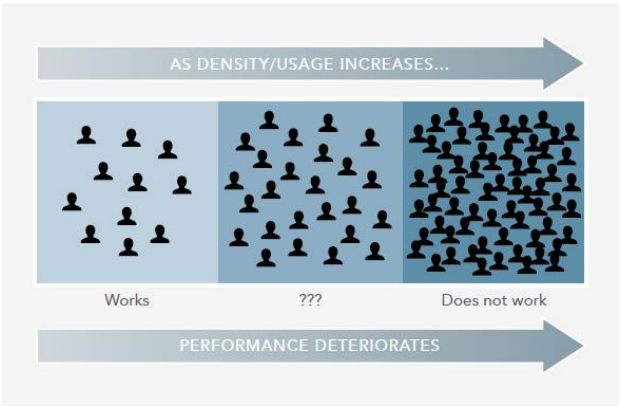
WiFi 6E vs. WiFi 7, roughly

- Max channel width
  - 160 MHz → 320 MHz
- Max MCS
  - 1024-QAM → 4096-QAM
- Links per device
  - 1 → up to 3 simultaneous (MLO)
- Spectrum used
  - Single band → can span 2.4/5/6 GHz at once
- Caveat, real-world gains are usually much smaller than the on-paper numbers

Wi-Fi 8 (IEEE 802.11bn)

- Motivation
  - Peak rates already exceed what most apps need
  - Users complain about glitches, lag, and dead spots
- Target applications
  - XR/AR/VR, gaming, industrial IoT, dense venues





Wi-Fi 8 (IEEE 802.11bn)

- Mechanisms – same as WiFi 7
  - Same bands (2.4/5/6 GHz)
  - 320 MHz channels
  - 4096-QAM
  - Peak PHY rate is not increased (~23 Gbps at 8 streams)
- Goals in real, busy networks
  - +25% throughput at a given SINR
  - -25% latency at the 95th percentile
  - -25% lost MPDUs, especially when moving between APs

Wi-Fi 8: Multi-AP Coordination

- Goals
  - Maintain low-latency coordination between APs
  - Manage the tradeoffs between efficiency, complexity, and signaling overhead

Wi-Fi 8: Multi-AP Coordination

- Co-SR: Coordinated Spatial Reuse
  - The AP that wins a transmit opportunity tells its neighbors how much interference it can tolerate
  - Neighbors can then transmit at the same time at reduced power instead of deferring

Wi-Fi 8: Multi-AP Coordination

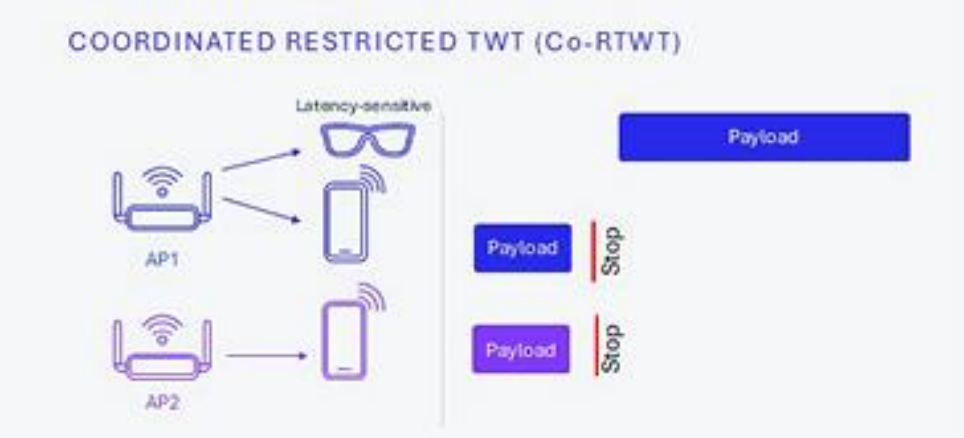
- Co-BF: Coordinated Beamforming
  - Neighboring APs share channel information so each one steers nulls toward the other's clients
  - Both APs can then transmit on the same channel at once without interfering

Wi-Fi 8: Multi-AP Coordination

- Co-TDMA
  - The AP that wins a TXOP gives slices of that time to neighboring APs
  - Each AP sends its own traffic in its assigned slot, so there are no collisions or backoff between them

Wi-Fi 8: Multi-AP Coordination

- Co-RTWT: Coordinated Restricted TWT
  - Neighboring APs align their R-TWT service periods across overlapping networks.
  - Each AP's reserved low-latency window stays protected from the others' traffic.

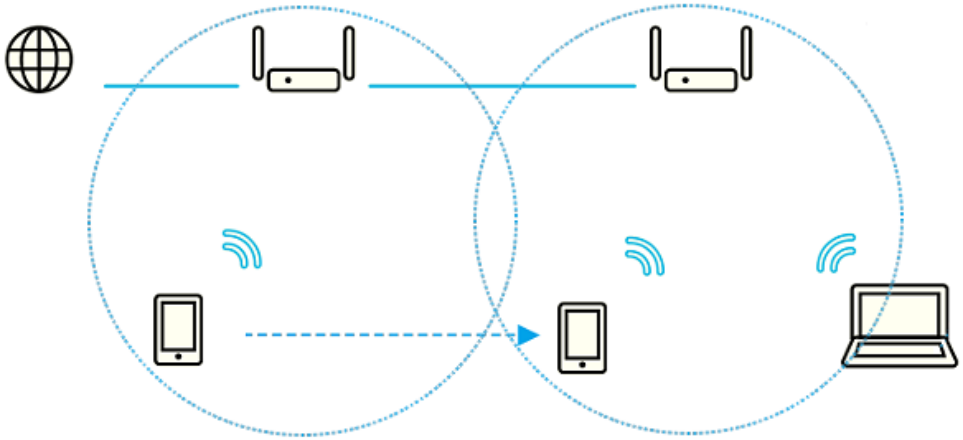


Wi-Fi 8: Multi-AP Coordination

- Co-CR: Coordinated Channel Recommendation
  - APs exchange channel measurements and recommend channels to each other
  - Neighbors can pick non-conflicting channels instead of each choosing independently

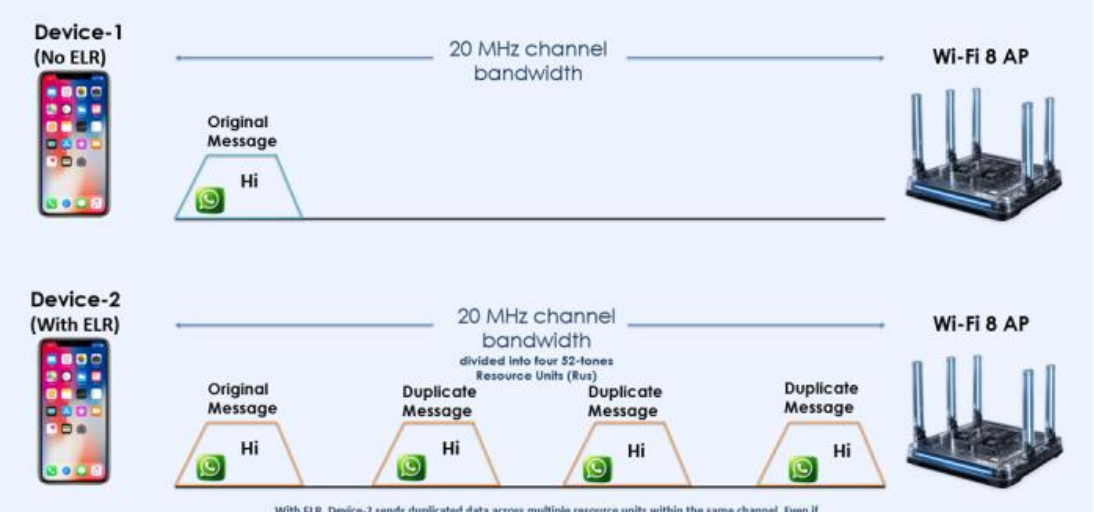
Wi-Fi 8: Roaming, Range, and Latency

- Seamless Roaming Domain (SMD)
  - APs share client state (keys, sequence numbers, capabilities)
  - Fewer drops and shorter gaps when a client moves between APs
  - Client can also move one link at a time with MLO to stay connected during handoffs



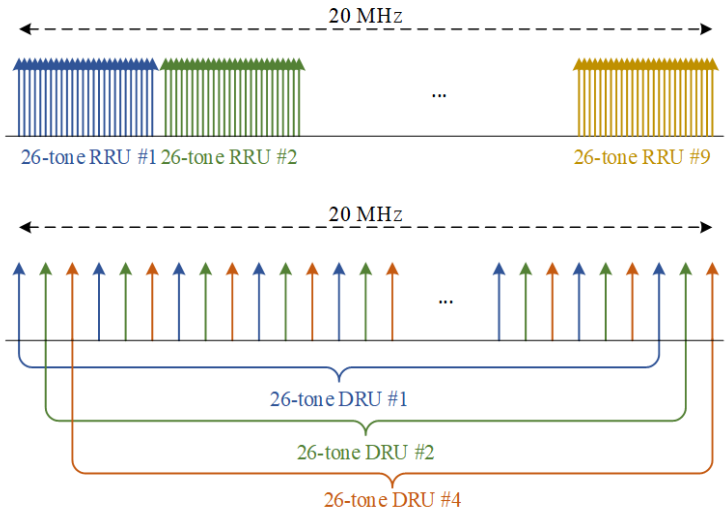
Wi-Fi 8: Roaming, Range, and Latency

- Enhanced Long Range (ELR) PPDU
  - Clients can hear high power APs but the AP may not hear the client
  - Use 20 MHz channel with only BPSK/QPSK
    - Concentrates the client's limited power in a narrow band with a very low-rate modulation, so the uplink reaches the AP



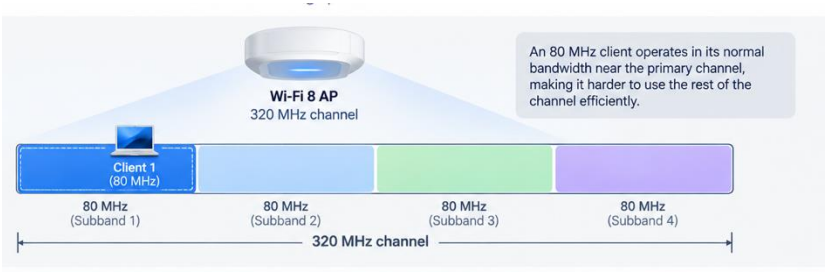
Wi-Fi 8: Roaming, Range, and Latency

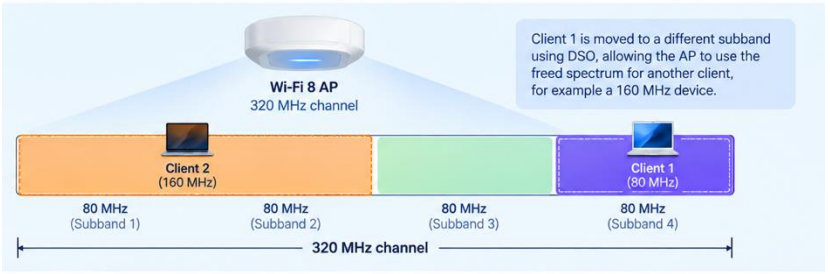
- Distributed-tone RUs (DRU)
  - Regulators cap power per MHz (especially in 6 GHz), so a narrow, contiguous RU can only use a small total power
  - DRU spreads tones across 20, 40, or 80 MHz
  - The same RU can then transmit at higher total power, which extends uplink range

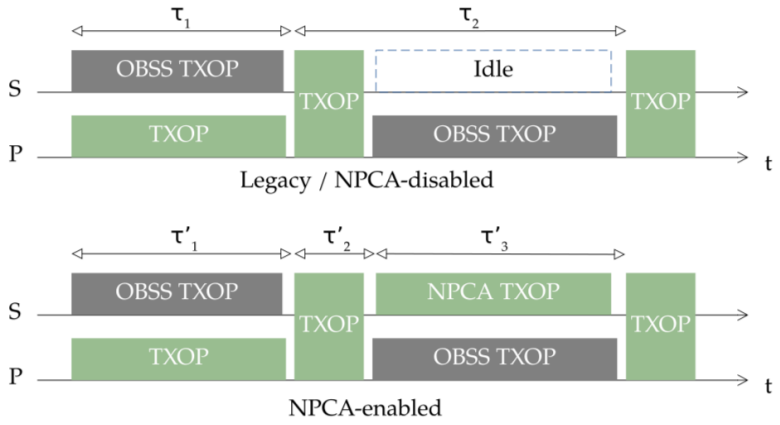


Wi-Fi 8: Better use of spectrum and priority

- Use non-primary channels when the primary is busy
  - DSO (Dynamic Subband Operation)
    - An AP on a wide channel can serve a narrow-bandwidth client on part of the channel
    - Other clients keep using the rest, instead of]dropping to the narrow client's width
  - NPCA (Non-Primary Channel Access)
    - Devices can switch to a non-primary channel and keep transmitting even if the primary 20 MHz channel is busy







Wi-Fi 8: Better use of spectrum and priority

- Cut long-tail latency
  - HIP EDCA
    - A new access category ranks above voice, with more aggressive contention settings, for the most time-critical traffic
  - TXOP preemption
    - A high-priority frame can interrupt a lower-priority transmission already in progress, instead of waiting for it to finish
    - Cuts the rare, long delays (tail latency) that hurt gaming and video calls
- Finer rate steps
  - New MCS values
    - Existing MCS steps are coarse, so a device often has to round down to a rate below what the channel could support
    - New intermediate values let rate adaptation get closer to the best rate

Wi-Fi 8: Status and Timeline

- Standardization (IEEE 802.11bn)
  - Task group formed May 2021; Draft 1.0 in July 2025
  - Draft 1.4 in March 2026; Draft 2.0 ballot slipped to mid-2026
  - Ratification targeted for ~May 2028 (some reports say as late as Sept 2028)
- Products
  - Pre-standard consumer chips and routers expected from late 2026 into 2027
  - Wi-Fi Alliance certification expected from ~2027 to early 2028
  - Same pattern as earlier generations: silicon ships before the standard is final
- What comes after?
  - IEEE formed an AI Offload study group in mid 2026
  - Early idea: APs running AI inference for nearby devices (smart glasses, robots)

Wi-Fi 6E vs. Wi-Fi 7 vs. Wi-Fi 8

	Wi-Fi 6E (11ax)	Wi-Fi 7 (11be)	Wi-Fi 8 (11bn)
Year	2021	2024	~2028 (target)
Bands	2.4 / 5 / 6 GHz	2.4 / 5 / 6 GHz	2.4 / 5 / 6 GHz
Max channel	160 MHz	320 MHz	320 MHz
Max modulation	1024-QAM	4096-QAM	4096-QAM
Peak PHY rate	~9.6 Gbps	~23 Gbps	~23 Gbps (no increase)
Key features	OFDMA, TWT, BSS coloring	MLO, multi-RU, puncturing	MAPC, SMD, ELR, DRU
Design goal	Efficiency in dense networks	Peak speed and capacity	Reliability and tail latency