Introduction to 802.11be / Wi-Fi7

Laurent Cariou
Intel
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Current Generations of Wi-Fi

Wi-Fi 6

- Based on IEEE 802.11ax
- 2.4, 5, 6 GHz band operation
- OFDMA, UL and DL MU-MIMO, target wake time (TWT), 1024-QAM
- Best-in-class WPA3 security
- Max data rate: 9.6 Gbps
- Launched Aug/2019

Wi-Fi 6E

- Extends Wi-Fi 6 with 6 GHz band operation*
- Launching Jan'2021

Wi-Fi 5

- Based on IEEE 802.11ac
- 5 GHz band operation
- Up to 8x8 MIMO, DL MU-MIMO, 80 MHz and 160 MHz channels, 256-QAM
- Max data rate: ~7 Gbps
- Launched June/2013

Wi-Fi 4

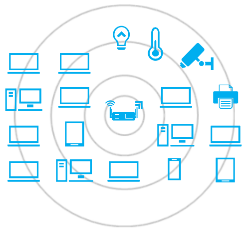
- Launched in 2007
- Max data rate: ~600 Mbps
- Up to 4x4 MIMO, 40 MHz channels, 64-QAM
- 2.4 and 5 GHz band operation
- Based on IEEE 802.11n

* 6 GHz operation subject to regulatory rules in each country.

Wi-Fi 6/6E: A Giant Leap Forward

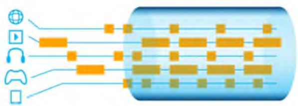
4X GREATER SCALABILITY

OFDMA enables managed, reliable, efficient connectivity across more devices. This means plenty of headroom for future growth or fewer APs required to support existing devices.



REDUCED INTERFERENCE

OBSS enhancements help routers and devices identify local traffic and tune out noise from other networks.

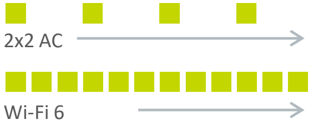


IMPROVED SECURITY

Wi-Fi 6 uses new WPA3 security features, enabling next-generation authentication and best-in-class encryption.

3X FASTER PERFORMANCE

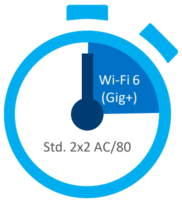
1024 QAM and support for optional 160 MHz channels enable clients and routers to deliver best-in-class Gigabit speeds for the office or home.



RESPONSIVE!

~75% LOWER LATENCY

Wi-Fi 6 helps slash lag times to give you the edge you need to win with OFDMA data management and OBSS interference avoidance features.



Increasingly stringent usage (e.g., industrial IoT, AR/VR, robotics, cloud gaming) requirements demand continued evolution

Wi-Fi 6E

- Use of 6 GHz unlicensed spectrum
  - Regulators opening unlicensed use at 6 GHz in more and more countries
  - 1,2 GHz of spectrum in the US, 600MHz in Europe, …
  - Some constraints to protect incumbents (Low Power Indoor mode, AFC mode)
- Huge benefits
  - Make use of 160 MHz channelization possible even in enterprise dense deployments
  - Help with congested 2.4/5 GHz bands

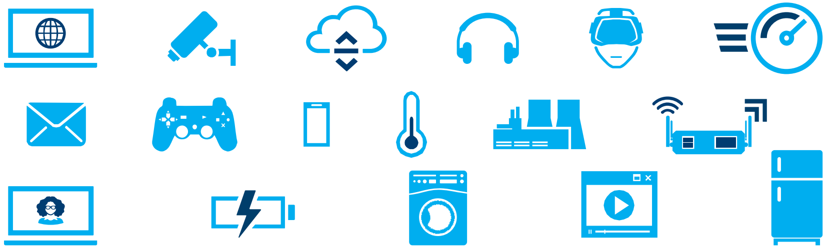
Up Next: Wi-Fi 7

Based on IEEE P802.11be

P802.11be project goals*

- Amendment to 802.11, building on 11ax
- Maximum throughput of at least 30 Gbps
- Frequency range: between 1 & 7.250 GHz
- Improvements to worst-case latency & jitter

Targeted usages



* http://www.ieee802.org/11/PARs/P802_11be_PAR_Detail.pdf

Key Wi-Fi 7 Features*

User Experience Data Rate

Spectrum Efficiency

Network Energy Efficiency

Connection Density

Key Enhancements

320 MHz channels
4096-QAM

Multi-link operation
Deterministic low latency

Multi-RU (puncturing)

Peak Data Rate

Cost Effective

Area Capacity

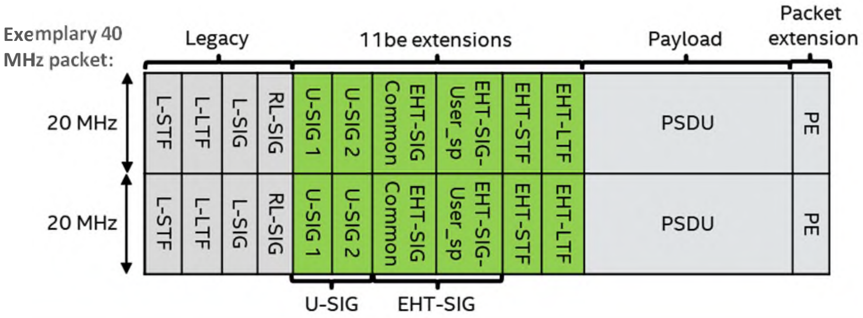
Low Latency

* Accurate as of June/2020. Feature set and their specification are subject to change.

PHY Enhancements: Basics

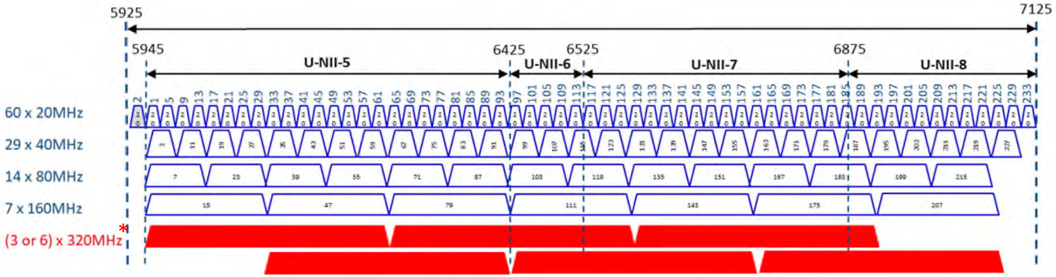
Preamble and packet format

- Universal SIG (U-SIG) defined for forward compatibility (e.g., version, UL/DL, TXOP duration)
- EHT-SIG with common and user-specific parts



Channelization and 320 MHz channels

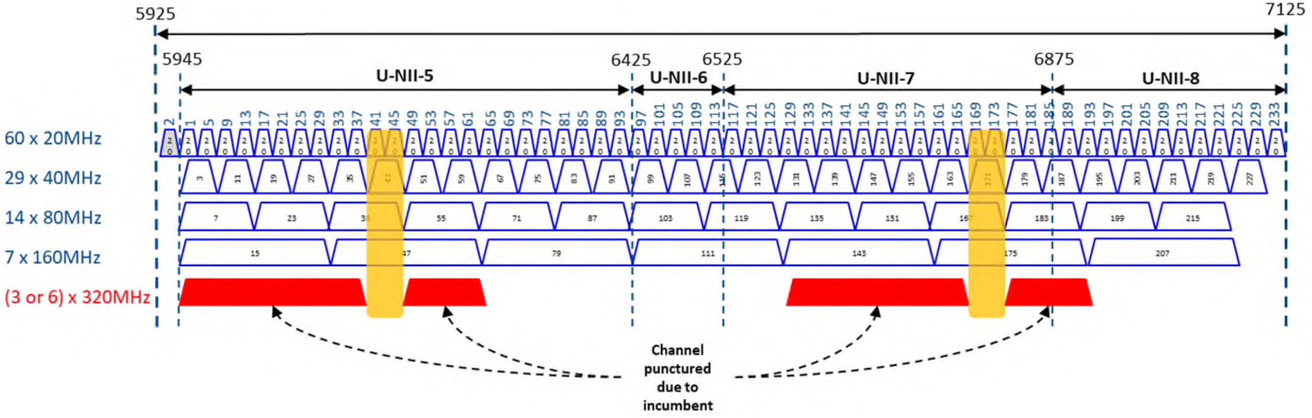
- Max single channel bandwidth increased from 160 MHz (Wi-Fi 6/6E) to 320 MHz
- Tone plan for 320 MHz and 160+160 MHz use duplicated 160 MHz tone plan based on Wi-Fi 6



* Number of 320 MHz channels dependent upon regulatory rules per country.

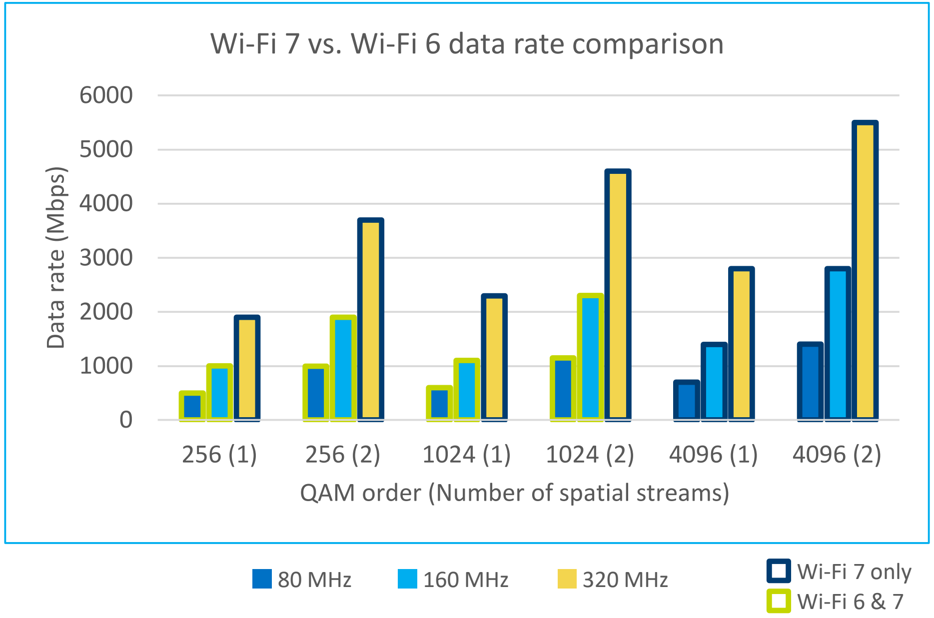
PHY Enhancements: Multi-RU (Puncturing)

- Multi-RU is created by puncturing the operating channel
  - Puncturing granularity = 20 MHz
- Main motivation is to avoid transmitting on frequencies that are locally unauthorized by regulation due to incumbent operation



PHY Enhancements: Data Rate

Parameter	Wi-Fi 6	Wi-Fi 7
Max channel bandwidth	160 MHz	320 MHz (3 channels in 6 GHz)
Highest modulation order	1024-QAM	4096-QAM
Max number of spatial streams	8	8
Max data rate*	~9.6 Gbps	~23.1 Gbps



Max data rate increase of about 2.4x compared to Wi-Fi 6

* This reflects the maximum theoretical data rate. Practical data rates depend on many factors, including on the capabilities of an AP and its associated clients.

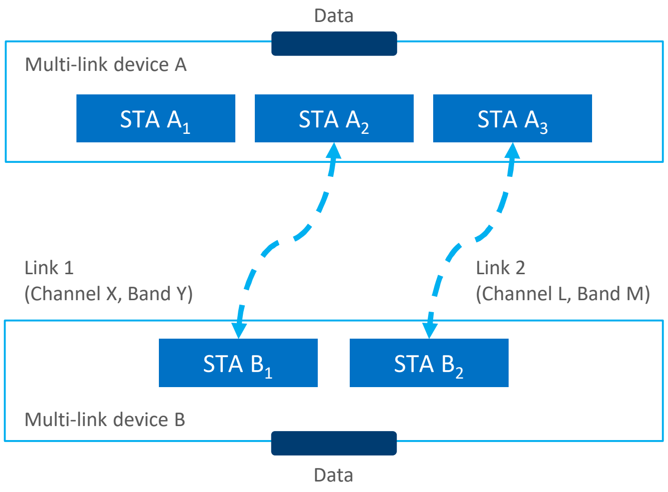
Multi-link Operation (MLO)

MLO enables link aggregation at the MAC layer

- A link is mapped to a channel and band

MLO brings benefits in multiple dimensions:

- Additive throughput for data flows split over links
  - **For two links (e.g., 5 GHz and 6 GHz), max aggregate data rate could reach 7.2x compared to Wi-Fi 6**
- Lower latency due to access to multiple links in parallel
- High reliability by packets duplication over multiple links
- Assign data flows to specific links based on app needs



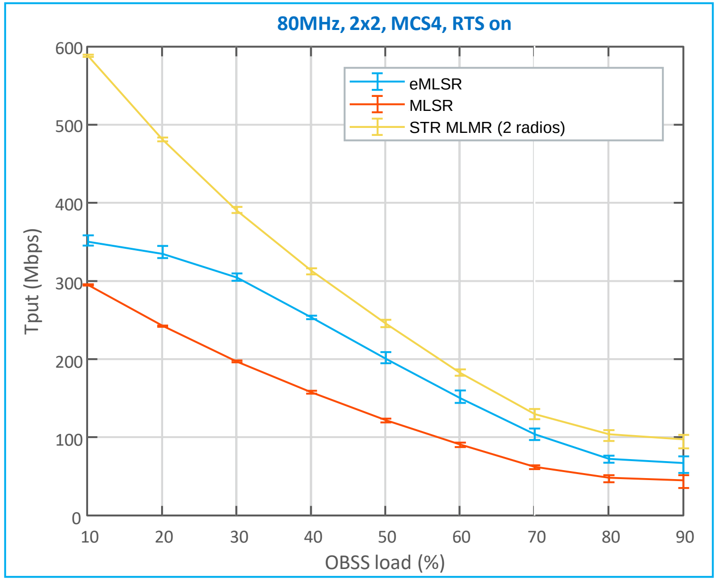
MLO provides higher throughput, lower latency and/or higher reliability, which are useful to a number of applications from VR/AR to industrial IoT

Multi-link Operation: Types of MLO

Different MLO implementation options are possible

MLO type	No. of full function 11be radios	Characteristics
Multi-link single radio (MLSR)	1	Able to RX and TX over one radio at a time
Enhanced MLSR (eMLSR)		Enhances MLSR with a reduced function radio to choose best link
Non-simultaneous TX and RX multi-link multi radio (Non-STR MLMR)	≥ 2	Able to simultaneously RX and TX over ≥ 2 radios, but only under certain constraints (e.g., freq. separation, aligned TX/RX)
STR MLMR		Able to simultaneously RX and TX over ≥ 2 radios

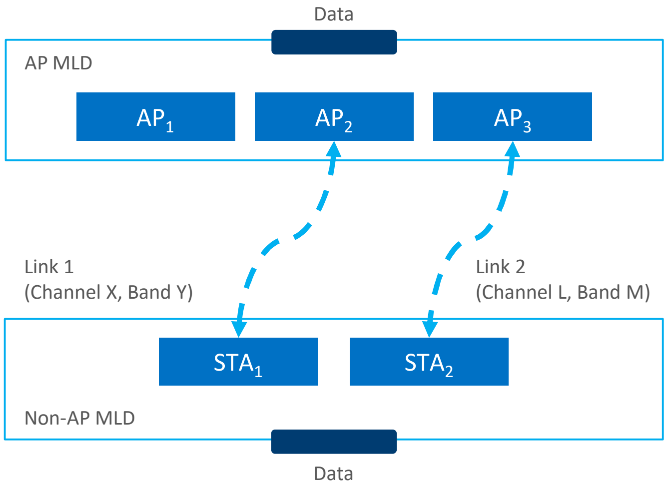
Complexity & performance



https://mentor.ieee.org/802.11/dcn/20/11-20-0562-01-00be-enhanced-multi-link-single-radio-operation.pptx

MLO Discovery, association, …

- Discovery of basic information of all APs of an AP MLD in Beacons and Probe Responses
- Complete discovery through Beacons in each link or through Multi-link Probe Request/Response
- Single Multi-Link association between MLDs
  - Lead to association of affiliated APs/STAs on each link that is set up
- Single security negotiation as well with same keys across all links for unicast data frames



MLO Link management

- Default mapping: all TIDs mapped to all links
  - STA of non-AP MLD wakes up on the link it wants to use to retrieve any frames
    - AP may recommend links for load balancing
- TID-to-link mapping
  - Negotiation of how TIDs are mapped

    to the different links

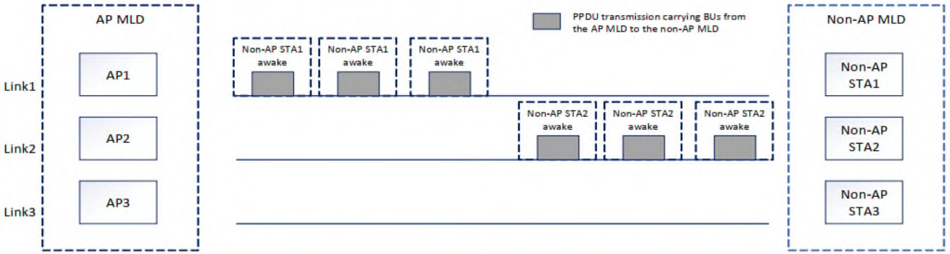


Figure 35-15—Example of link transition operation by a single radio non-AP MLD using power states

- Can lead to one link being disabled (not used)
  - An AP MLD can disable one AP/link for all associated non-AP MLD for power save/reconfiguration reasons

R-TWT: Restricted Target Wake Time

- Service periods dedicated to traffic delivery of prioritized traffic of some STAs (members)
- To increase changes of medium access for the delivery of this traffic, goal is that all STAs end their TxOP before the start of the Service Period, so that AP has very high change to win the medium at that time

Wi-Fi 8

- Discussion started around a year ago in IEEE802.11 for opening a new mainstream project for Wi-Fi 8
  - Will get a new name for the main program: 802.11bn
  - mmWave operation under a parallel program: IMMW SG
- Main trends:
  - Applications like XR will become a key driver and are expected to become mainstream in few years in multiple/most deployment scenarios, setting stringent requirements for deterministic low latency and throughput
  - Toward 10Gig Wi-Fi in clients with 2 spatial streams
  - More and more P2P links
- Candidate features:
  - Multi-AP coordination
  - Features for more deterministic latency

Wi-Fi8 IEEE 802.11 Timeline

TGbe (Wi-Fi 7)

- Jul 2018: SG creation
- Jan 2019: PAR approved
- May 2019: First TG meeting
- May 2021: D1.0 Letter Ballot
- Mar 2022: D2.0 LB
- Nov 2022: D3.0 LB
- Mar 2024: Final 802.11 WG approval

TGbn (Wi-Fi 8)

- July 2022: SG creation
- Mar 2023: PAR approved
- November 2023: First TG meeting
- May 2025: D1.0 Letter Ballot
- Mar 2026: D2.0 LB
- Nov 2026: D3.0 LB
- Mar 2028: Final 802.11 WG approval

UHR SG decisions on KPI/objectives for 802.11bn

In March 2023, the SG converged on the key PKIs/objectives for 802.11bn PAR:

- **Throughput at different SINR levels (Rate over Range)**
  - Not peak throughput increase as for previous generations, but enhancements of actual throughput experienced on the field, or area throughput
- **Worst case latency and jitter**
  - Improved predictability for traffic's QoS requirements
  - Including mobility between BSSs

  Considering scenarios with an isolated BSS and also scenarios with overlapping BSSs (coordination)

- Power save improvements (including for APs and mobile APs)
- Improved P2P operation (coordination)

IMMW Study Group (Integrated mmWave)

Study group will start in November 2023

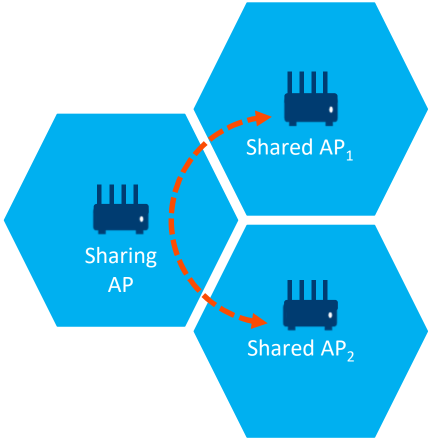
Goal is to have a very narrow scope:

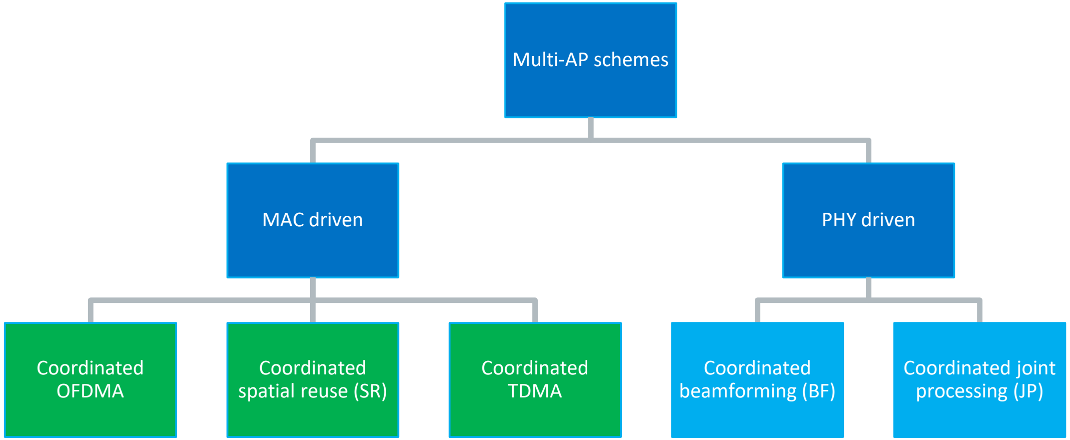
- limit the scope to the minimum necessary to enable a lower band PHY to operate in mmWave
  - critical to not only ensure minimal standard changes, but also minimal implementation complexity and larger market adoption
- Leave optimizations and enhanced features for future generations
  - Pave the way for long term evolution of 802.11 and its market adoption: Potential for enhanced features for multiple generations
  - In other words: just focus on the least complexity solution to enable operation in the band
- Focus on devices supporting operation in sub 7 GHz AND mmWave to benefit from Multi-Link Operation (MLO) framework

Multi-AP Features

Multi-AP refers to a collection of features that rely on direct AP coordination to achieve desired network performance goals

Different flavors of multi-AP solutions are being considered





Multi-AP Features: MAC Driven

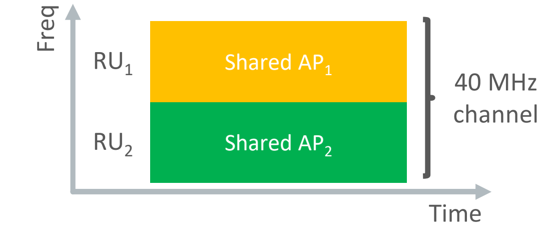
Coordinated OFDMA, Spatial Reuse (SR) & TDMA

A sharing AP triggers shared AP(s) so that shared AP(s) can perform one of:

Coordinated OFDMA

AP(s) transmit simultaneously to their associated STAs on different OFDMA resource units

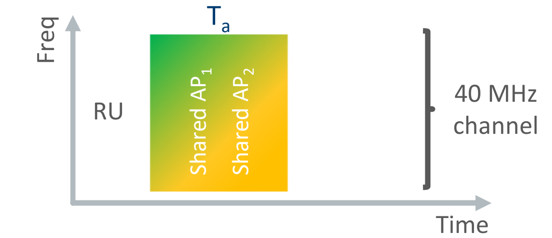
Example



Coordinated SR

AP(s) transmit simultaneously to their associated STAs on the same resource units

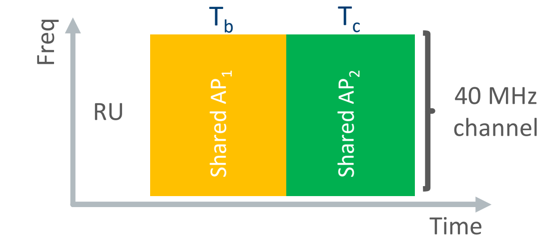
Example



Coordinated TDMA

AP(s) take turn in transmitting to their associated STAs on the same resource units

Example



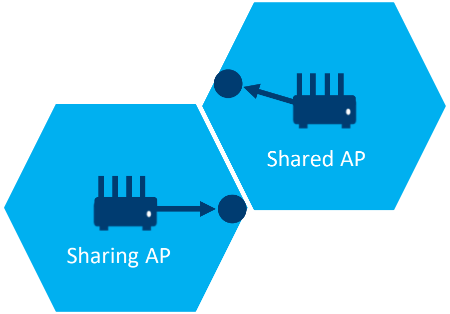
Multi-AP Features: PHY Driven

Coordinated BF or JP

Coordinated BF

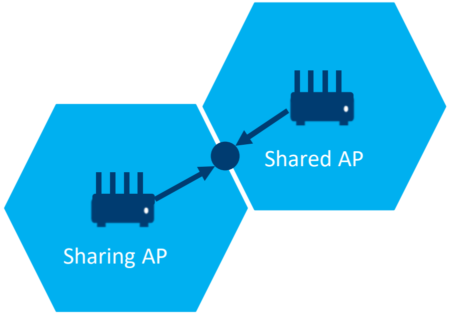
A sharing AP can sound channels from their own STAs and from STAs associated with a shared AP

Sharing AP can then transmit simultaneously to its own STAs on the same resources as shared AP is transmitting to its own STAs, while nulling the interference towards the shared AP's STAs



Coordinated JP

For STAs that are able to receive from multiple APs, JP enables the use of the sum of antennas from all the transmitting APs



Complexity & performance

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