Next-generation Wi-Fi

Wi-Fi 7 and beyond

Carlos Cordeiro
CTO, Wireless Communications
Intel Corporation
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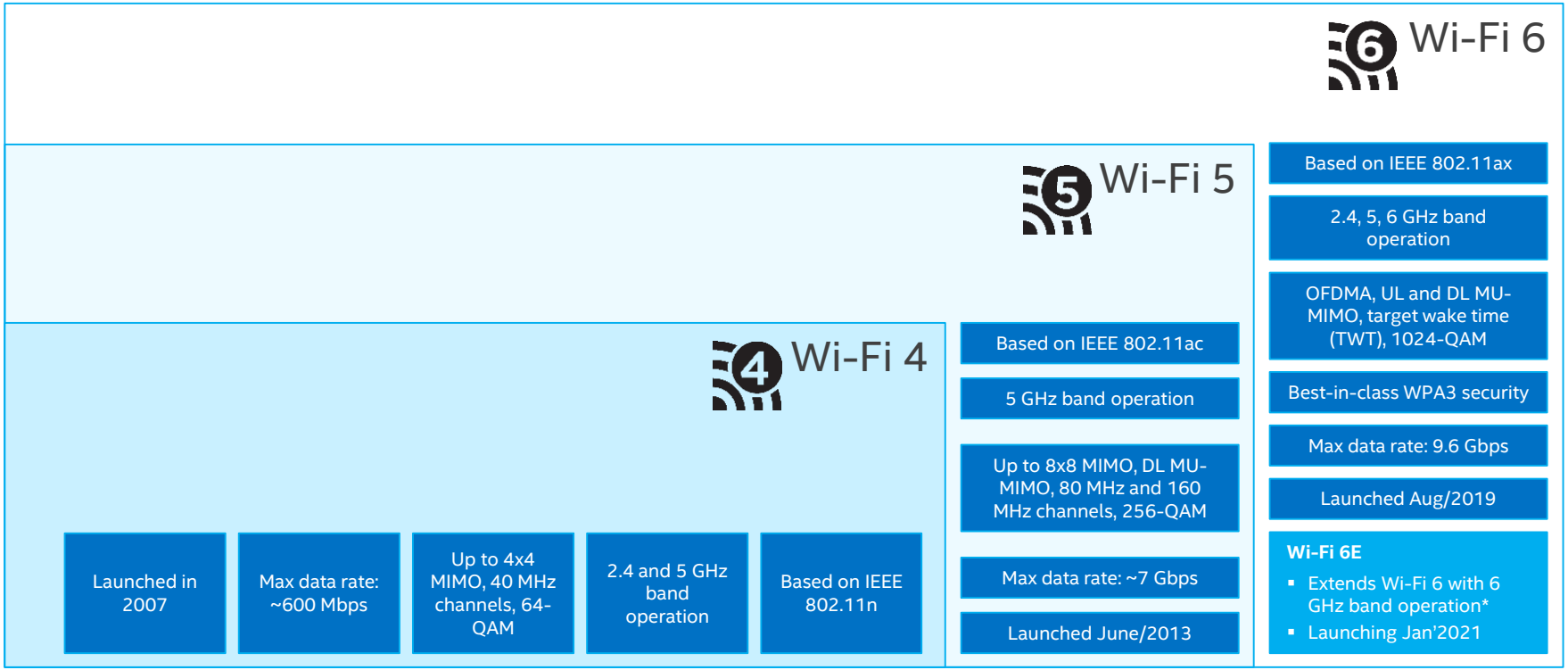
Agenda

- Wi-Fi Generations
- Wi-Fi Market and Growth
- Major Trends Impacting Wireless Evolution
- Fundamentals of Wi-Fi 7
- Beyond Wi-Fi 7

Current Generations of Wi-Fi

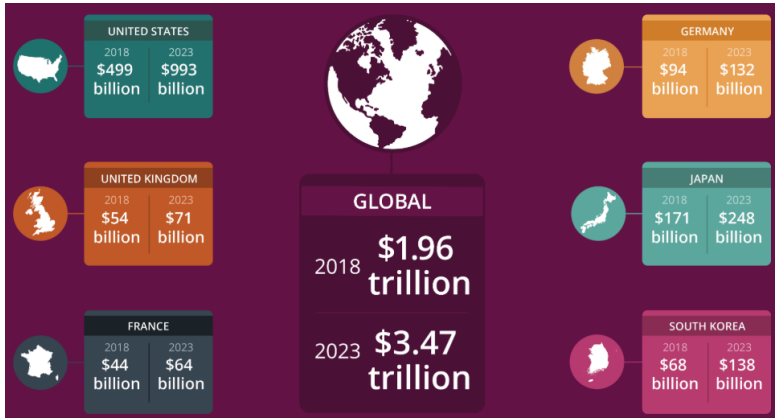


* 6 GHz operation subject to regulatory rules in each country.

Wi-Fi Market Economic Value

Wi-Fi economic value

~2 trillion in economic value in 2018



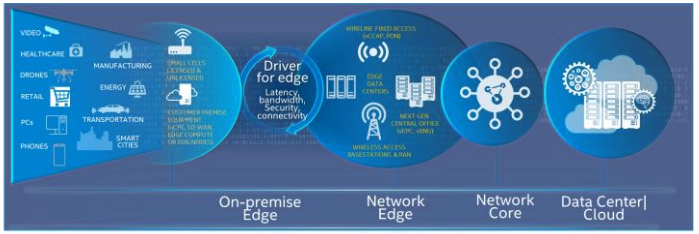
https://www.wi-fi.org/value-of-wi-fi

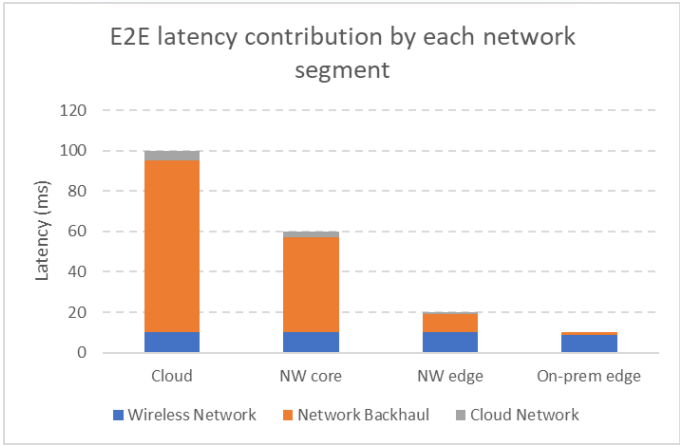
By 2022, ~60% of global mobile traffic will be offloaded to Wi-Fi and 51% of total IP traffic will be Wi-Fi*

* https://www.networkworld.com/article/3341099/wi-fi-6-5g-play-big-in-ciscos-mobile-forecast.html

New Experiences Demand Continuous Improvement

- New experiences (e.g., industrial IoT, 3D/XR content, real-time collab.) demand **more responsive connectivity**
- Compute shifting closer to the user, thereby **redefining end-to-end (E2E) network performance**
  - e.g., low, single-digit and sub-1ms latency become broadly available
- Low E2E latency across the network enables new services and experiences



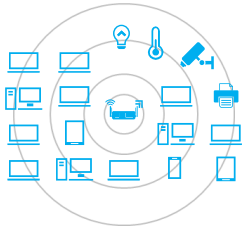


High performance wireless access essential to meet growing demand

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

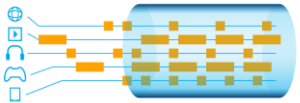
4X GREATER SCALABILITY

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.



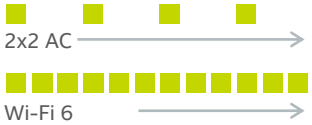
IMPROVED SECURITY

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

Improved Protection

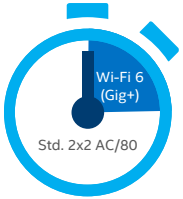
3X FASTER PERFORMANCE

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

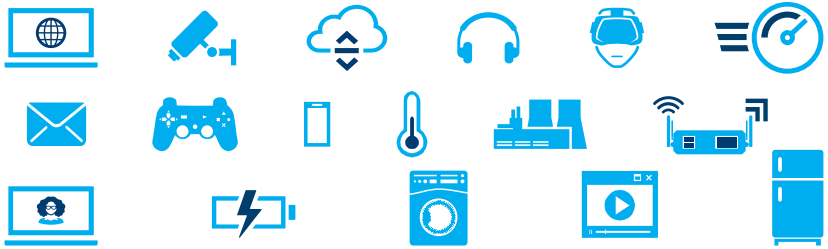
Up Next: Wi-Fi 7

Based on IEEE P802.11be

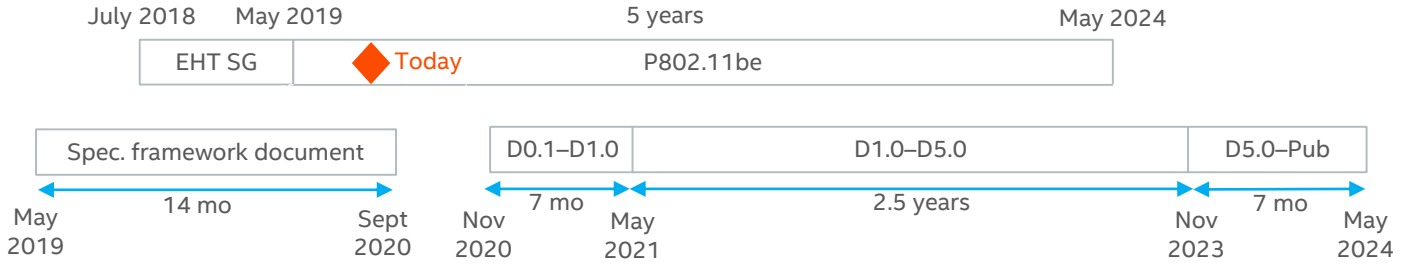
P802.11be project goals*

- 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



Target timeline



* 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
16 spatial streams

Multi-link operation
Multi-AP operation
Deterministic low latency

Multi-RU (puncturing)

Peak Data Rate

Cost Effective

Area Capacity

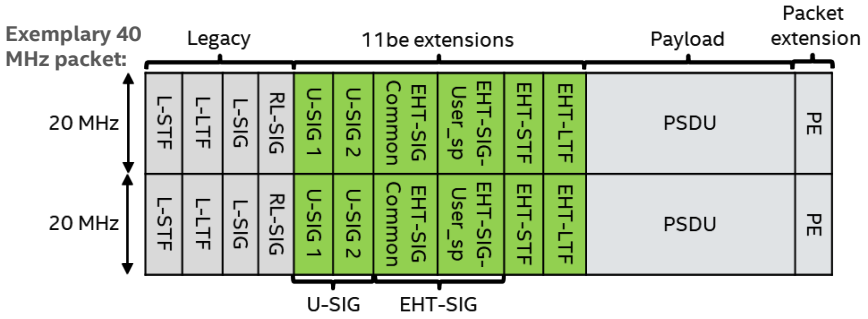
Low Latency

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

PHY Enhancements: Basics

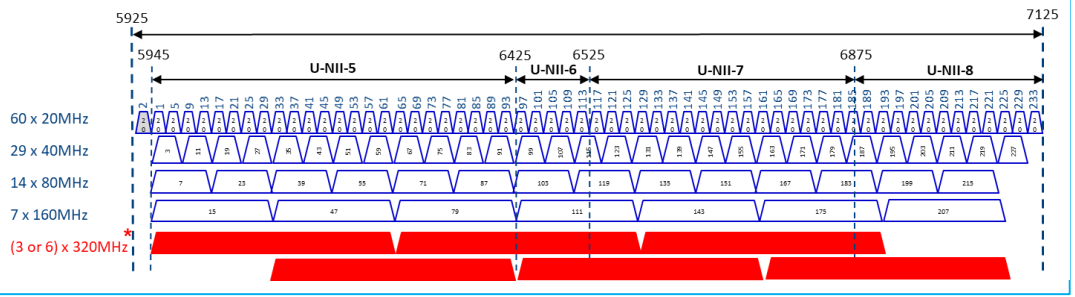
Preamble and packet format

- 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

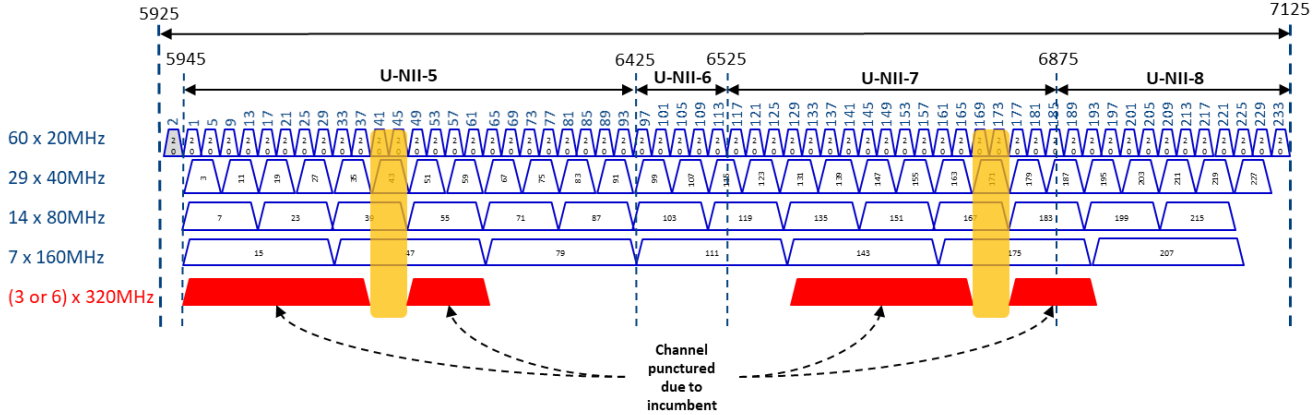
- Max single channel bandwidth increased from 160 MHz (Wi-Fi 6/6E) to 320 MHz
- Tone plan for 320 MHz use duplicated 160 MHz tone plan based on Wi-Fi 6



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

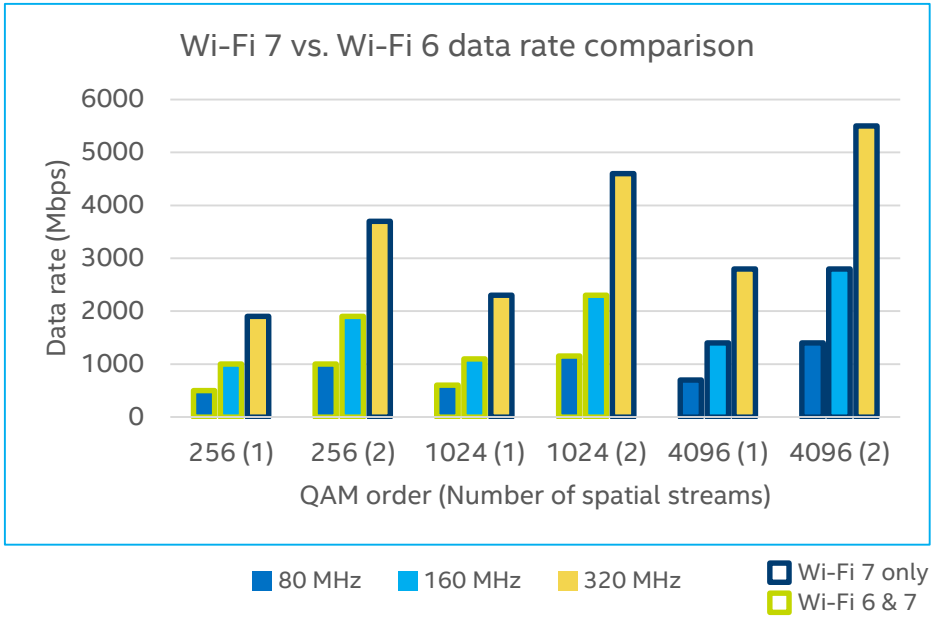
PHY Enhancements: Multi-RU (Puncturing)

- 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	16
Max data rate*	~9.6 Gbps	~46.1 Gbps



Max data rate increase of about 4.8x 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.

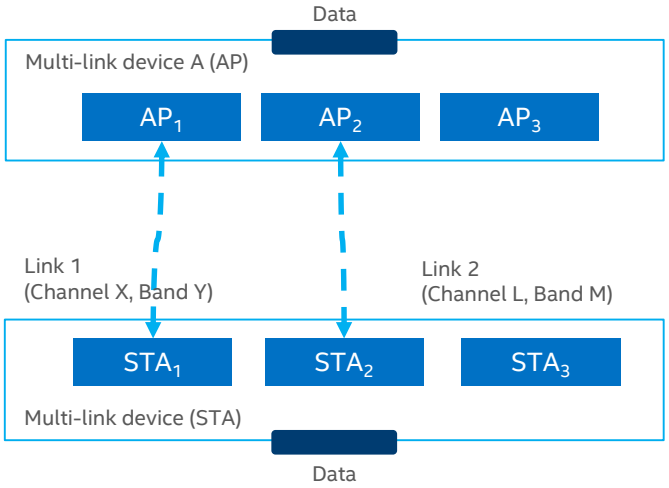
Multi-link Operation (MLO)

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



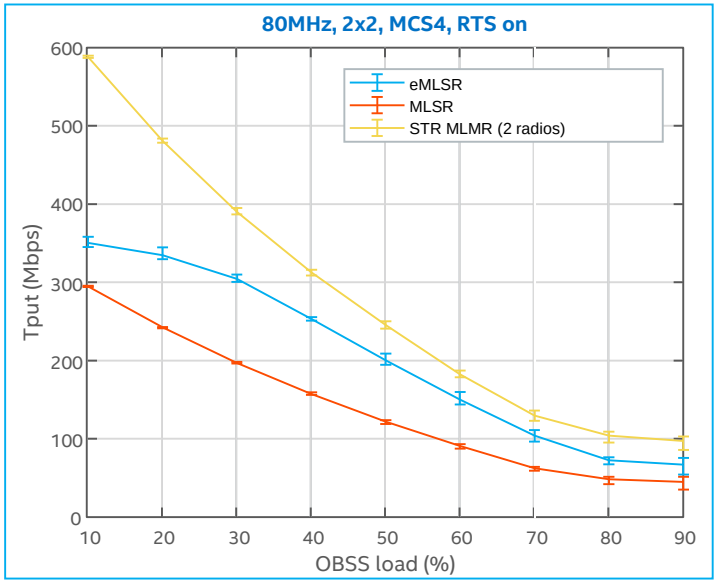
MLO provides higher throughput, lower latency and/or higher reliability, which are useful to a number of applications from VR/AR to industrial IoT

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

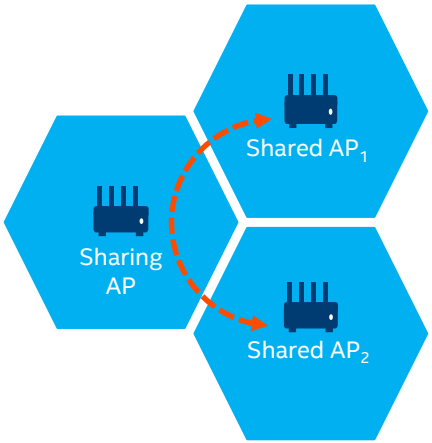


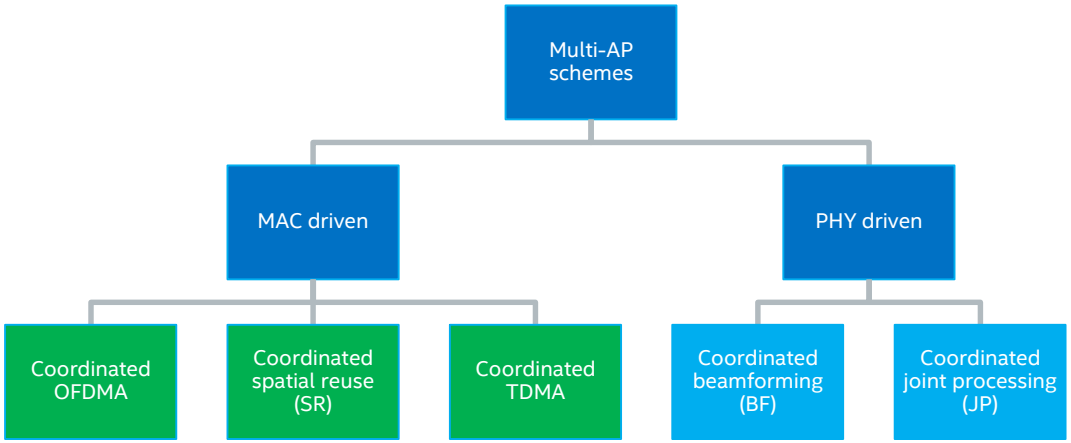
https://mentor.ieee.org/802.11/dcn/20/11-20-0562-01-00be-enhanced-multi-link-single-radio-operation.pptx

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

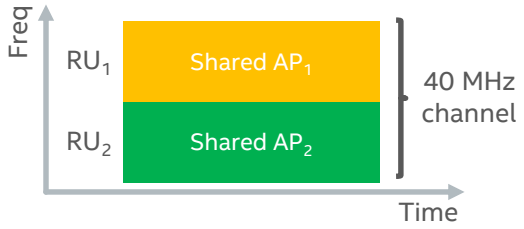
Coordinated OFDMA, Spatial Reuse (SR) & TDMA

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

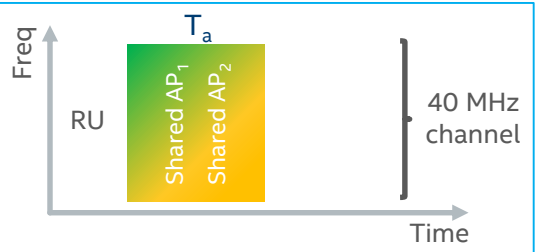
Example



Coordinated SR

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

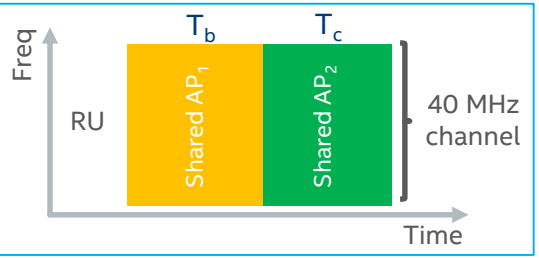
Example



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

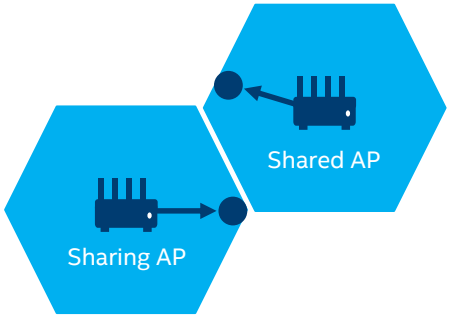
A sharing AP can sound channels from their own STAs and from STAs associated with a shared AP

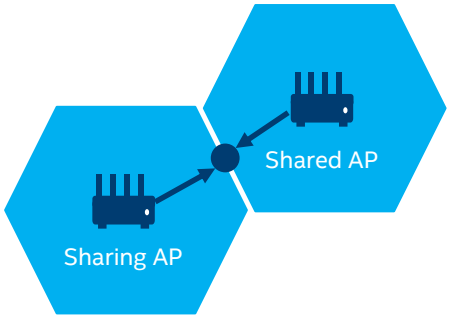
Sharing AP can then transmit simultaneously to its own STAs on the same resources as shared AP is transmitting to its own STAs, while nulling the interference towards the shared AP's STAs

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



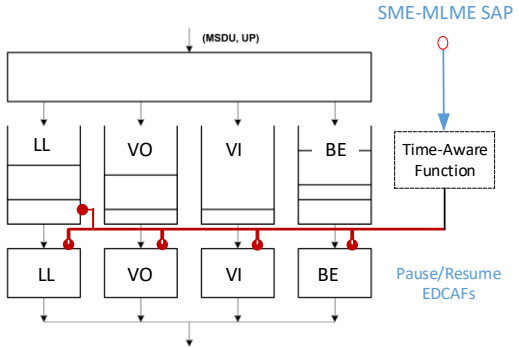


Deterministic Low Latency Enhancements

- **Wi-Fi 6 can achieve single-digit millisecond** latency, but the worst-case latency can be high in congested environments
- With the introduction of features like multi-link operation, multi-AP and 320 MHz channels in Wi-Fi 7, latency will be reduced even further
- However, to provide deterministic low latency required by some usages (e.g., industrial IoT, AR/VR), new schemes need to be defined

Potential Wi-Fi 7 features for deterministic low latency

- Define QoS provisioning model with dedicated, deterministic, low-latency (LL) and reliable access category
- Scheduled channel access with 802.1 TSN functionality
- Packet preemption for predictable channel access
- Limit TXOP duration across networks



https://mentor.ieee.org/802.11/dcn/20/11-20-0418-01-00be-low-latency-service-in-802-11be.pptx

OpenRoaming: Anywhere & Any Network Connected Wi-Fi Clients

Problem Statement

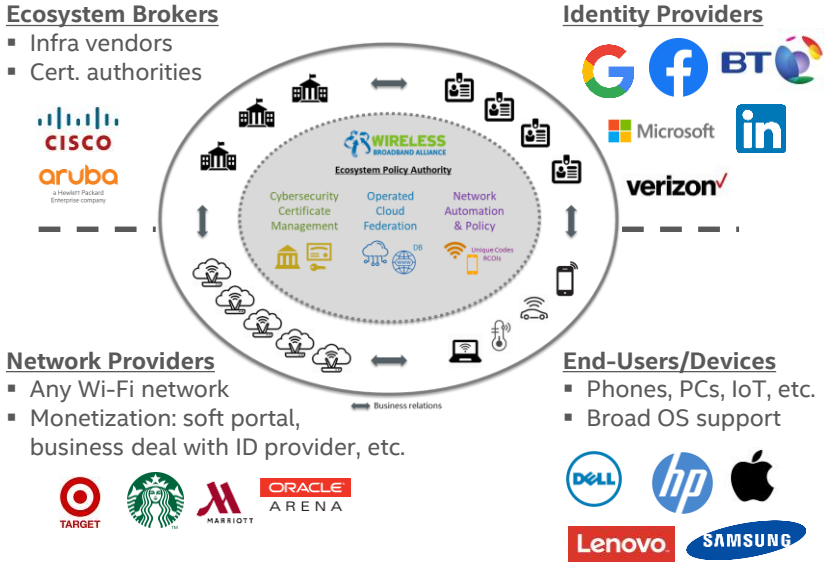
Wi-Fi hotspots can be found virtually everywhere, but clients connecting to these hotspots are either disallowed (e.g., lack of credentials) or cumbersome (e.g., captive portal)

Solution

OpenRoaming (OR) is an industry initiative that aims at connecting clients to Wi-Fi networks as seamless and pervasive as in cellular

- Based on Passpoint technology
- Scalable, many-to-many business relationships

OpenRoaming Players



OpenRoaming enables seamless connectivity of Wi-Fi clients across networks

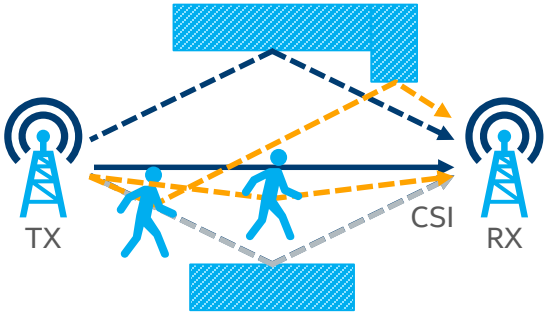
Wi-Fi Sensing

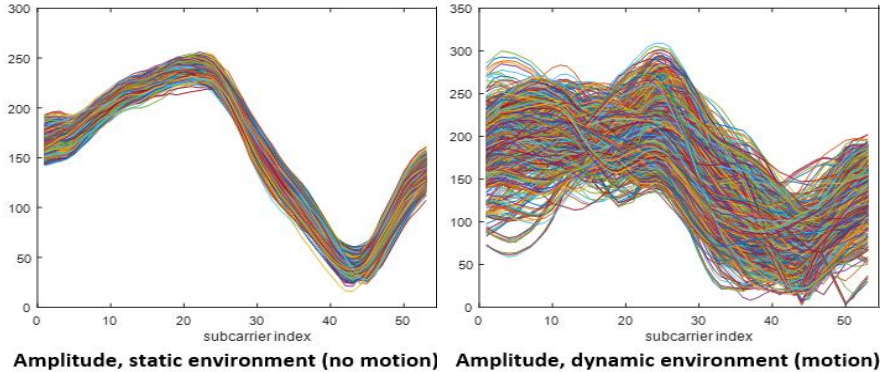
Wi-Fi sensing exploits channel changes measured by amplitude and phase

- Channel varies as changes in the environment alter the paths
- ML/signal processing can infer the cause (e.g., human presence, activity)
- Single device or multi-device sensing possible

IEEE 802.11 established a study group on Wi-Fi sensing (likely to become 802.11bf)

- Applies to 2.4/5/6/60 GHz





Amplitude, static environment (no motion) Amplitude, dynamic environment (motion)

Applications of Wi-Fi Sensing

Enterprise

Security, environment control

Wake on approach, walk away lock

Conference room occupancy

Gesture control

Residential

Security, environment control

Elderly monitoring

Baby monitoring

Gesture control

Retail and Hospitality

Environment control, Smart housekeeping

Signage efficiency

Gesture control

Capabilities

- Motion detection
- Proximity detection
- People counting
- Human activity recognition
- Vital signs detection

Wi-Fi Continues to Transform the Landscape

New Wi-Fi 7 innovations

320 MHz channels, multi-link operation, 4K-QAM, multi-AP, deterministic low latency

Wi-Fi 7 will build on Wi-Fi 6/6E

- **Need to open the entire 1200 MHz of the 6 GHz band for unlicensed use**
- Optimal use of the 6 GHz band, even lower latency, even higher throughput, even higher reliability, even more secure

Wi-Fi will become even better

- Video streaming, video/voice conferencing, wireless gaming, real-time collaboration, cloud/edge compute, industrial IoT, immersive AR/VR, interactive telemedicine, etc.
- OpenRoaming and Wi-Fi sensing

The future is bright for Wi-Fi!

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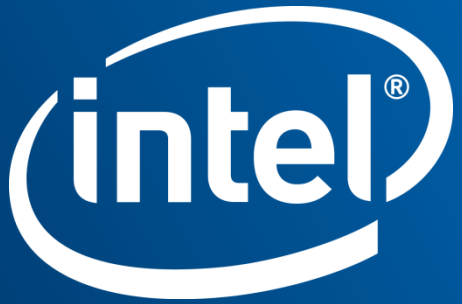
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