A Short Note Regarding the Terminology

born in 1990

born in 1999

Current release: 802.11ax == **Wi-Fi Generation 6**
Upcoming release: 802.11be == **Wi-Fi Generation 7**

Moore's Law → Higher Sample Rate → Increasing Link Bandwidth

Evolution of Wi-Fi

- 802.11n (Wi-Fi 4) [2]:
  - Single-user MIMO
  - Packet aggregation
- 802.11ac (Wi-Fi 5) [2]:
  - Multi-user MIMO (Downlink)
  - Channel bonding
- 802.11ax (Wi-Fi 6):
  - OFDMA
  - Multi-user MIMO (Uplink)
- 802.11be (Wi-Fi 7?):
  - Focus of this tutorial

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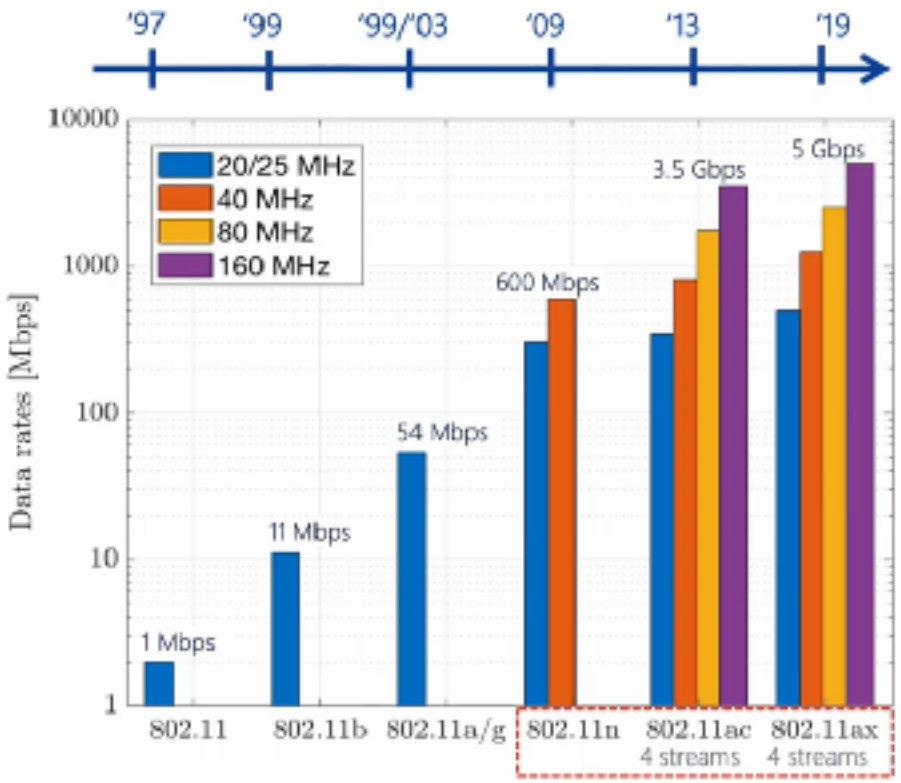
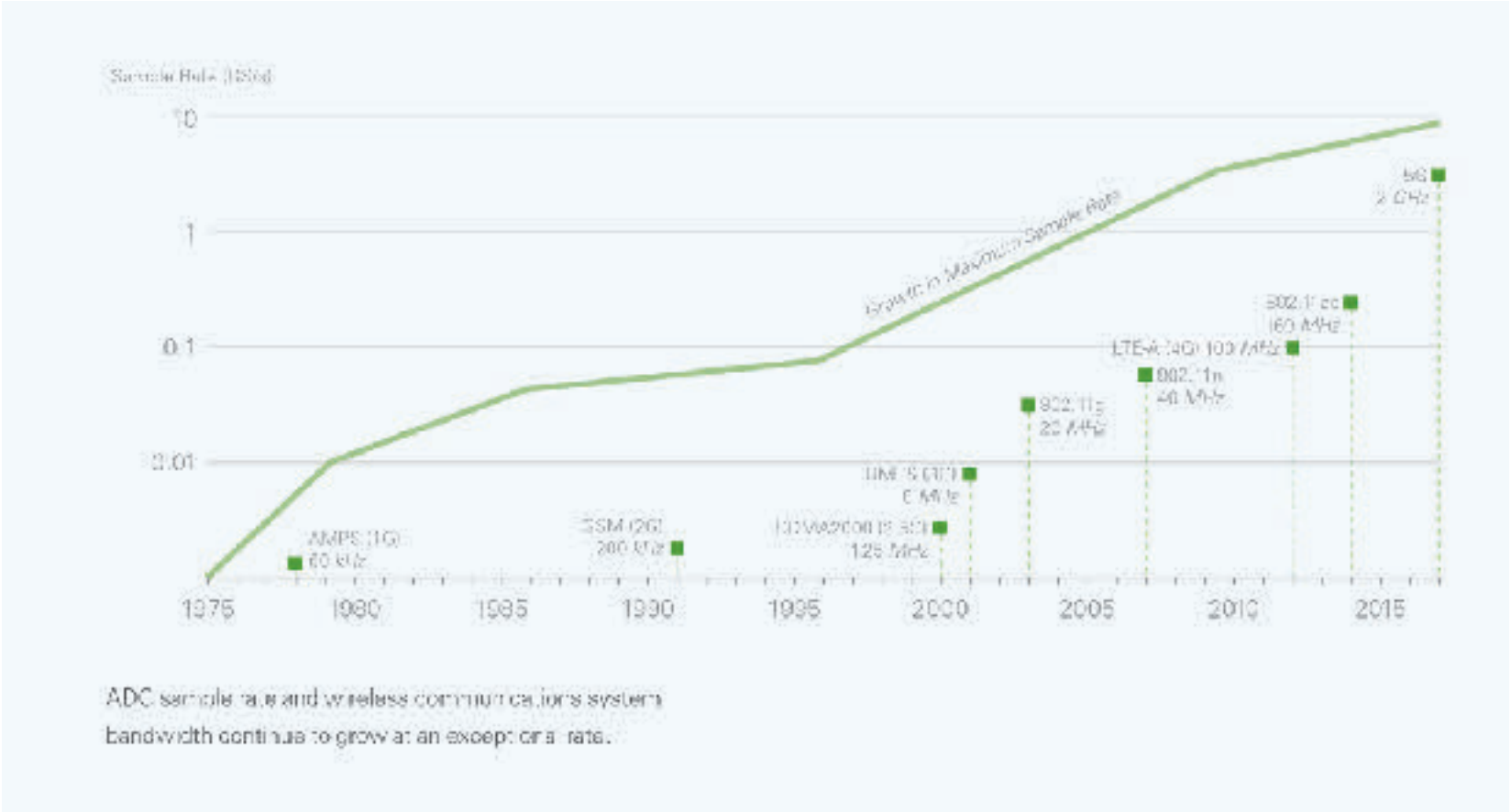


Moore's Law → Higher Sample Rate → Increasing Link Bandwidth



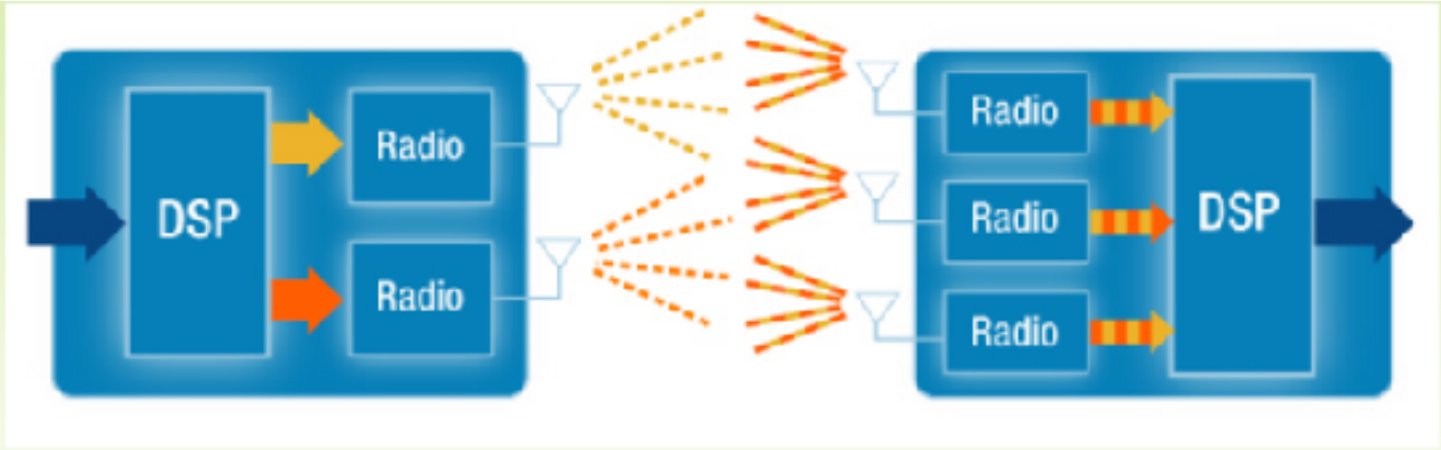
ADC sample rate and wireless communications system bandwidth continue to grow at an exceptional rate.

Moore's Law → Multiple RF Chains + Energy Efficient Matrix Computations

MIMO

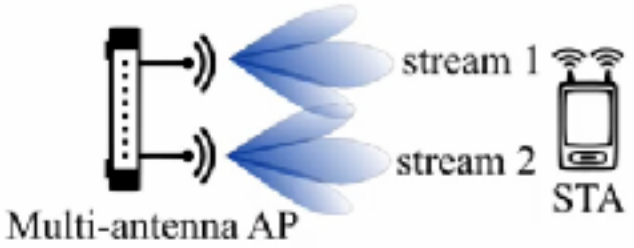
Multiple Input - Multiple Output

(introduced by IEEE802.11n = WiFi 4)

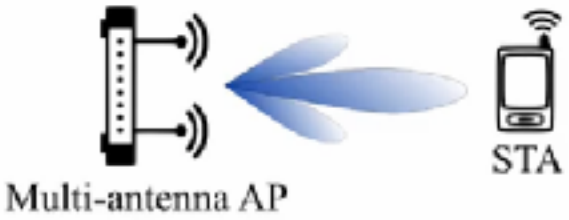


MIMO Variants

- Single-user techniques (802.11n/ac/ax) [43]
  - SU-MIMO
    - Up to min (N_{AP}, N_{STA}) streams
    - Only enabled for
      - High SINRs
      - Non-line-of-sight propagation



  - Beamforming
    - Regulations do not allow to focus energy on a given spatial direction [12]



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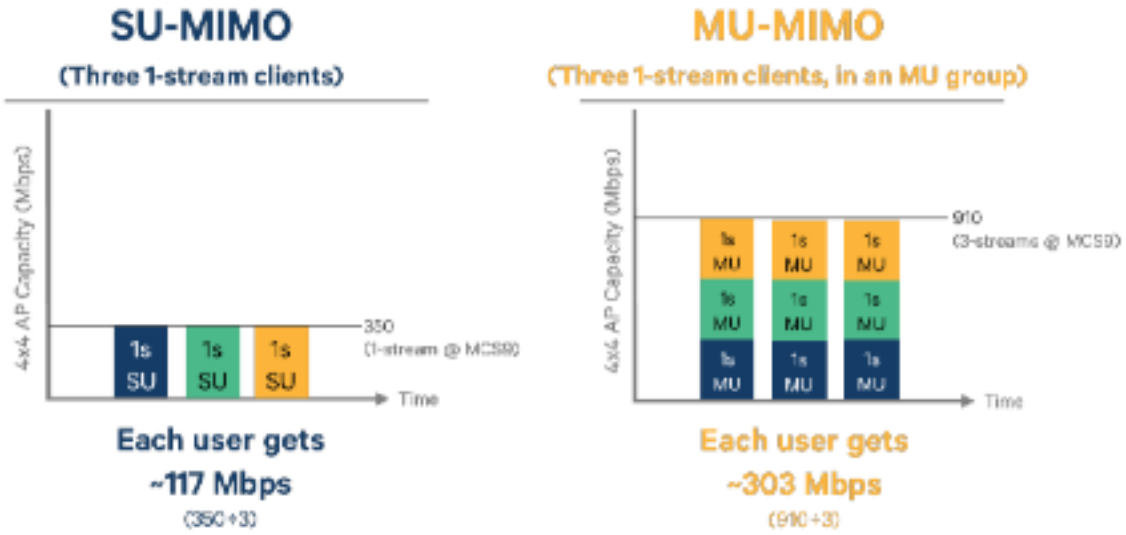
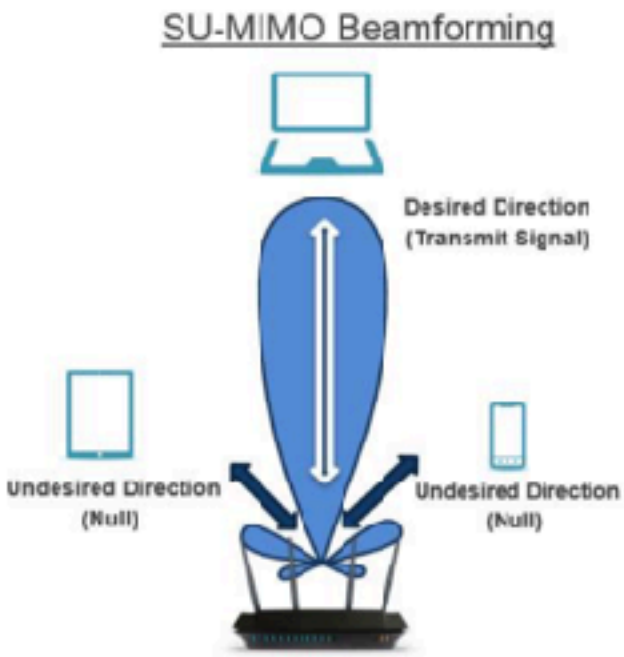
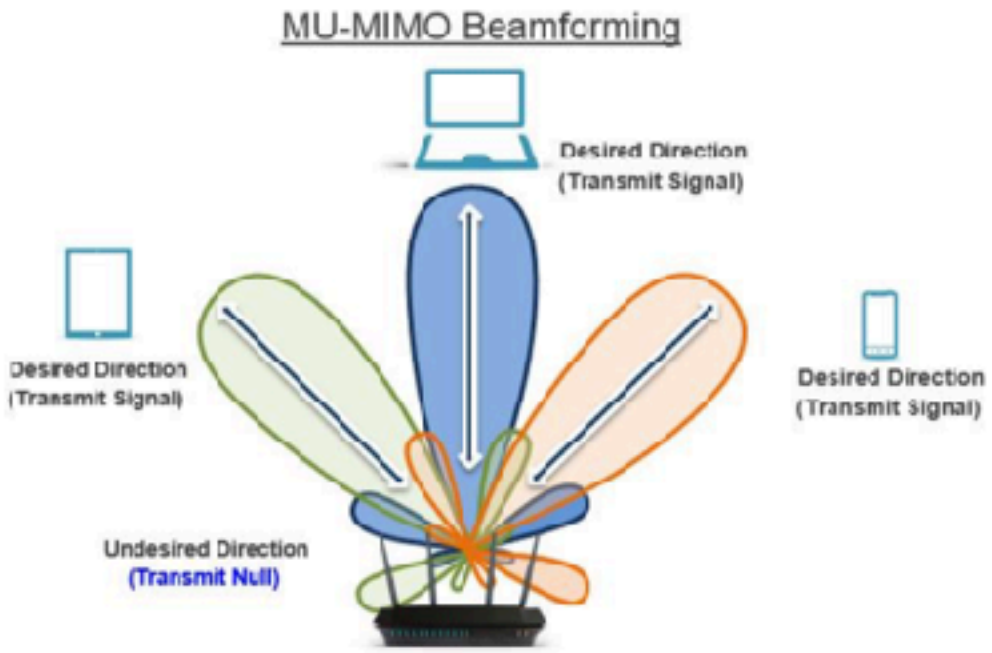
Multi-User MIMO

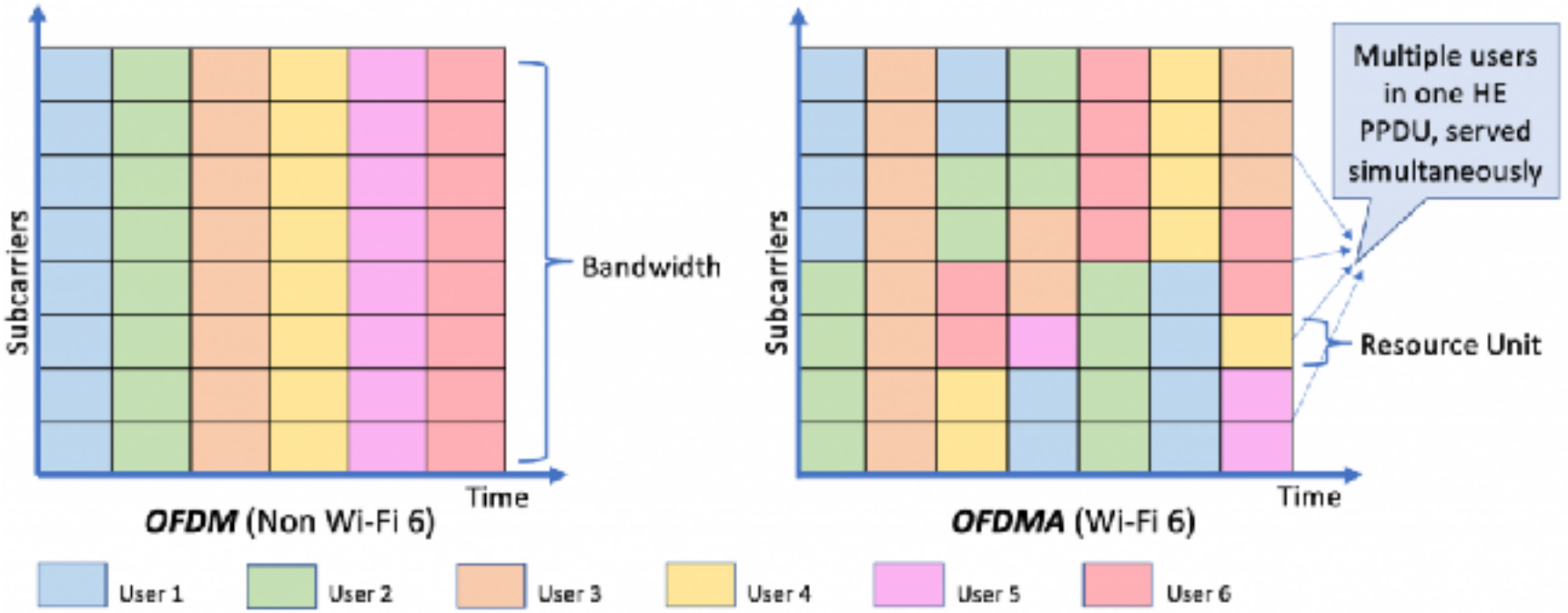


Multi-User MIMO Beamforming





“OFDMA” = Orthogonal Freq. Div. **Multiple-Access**



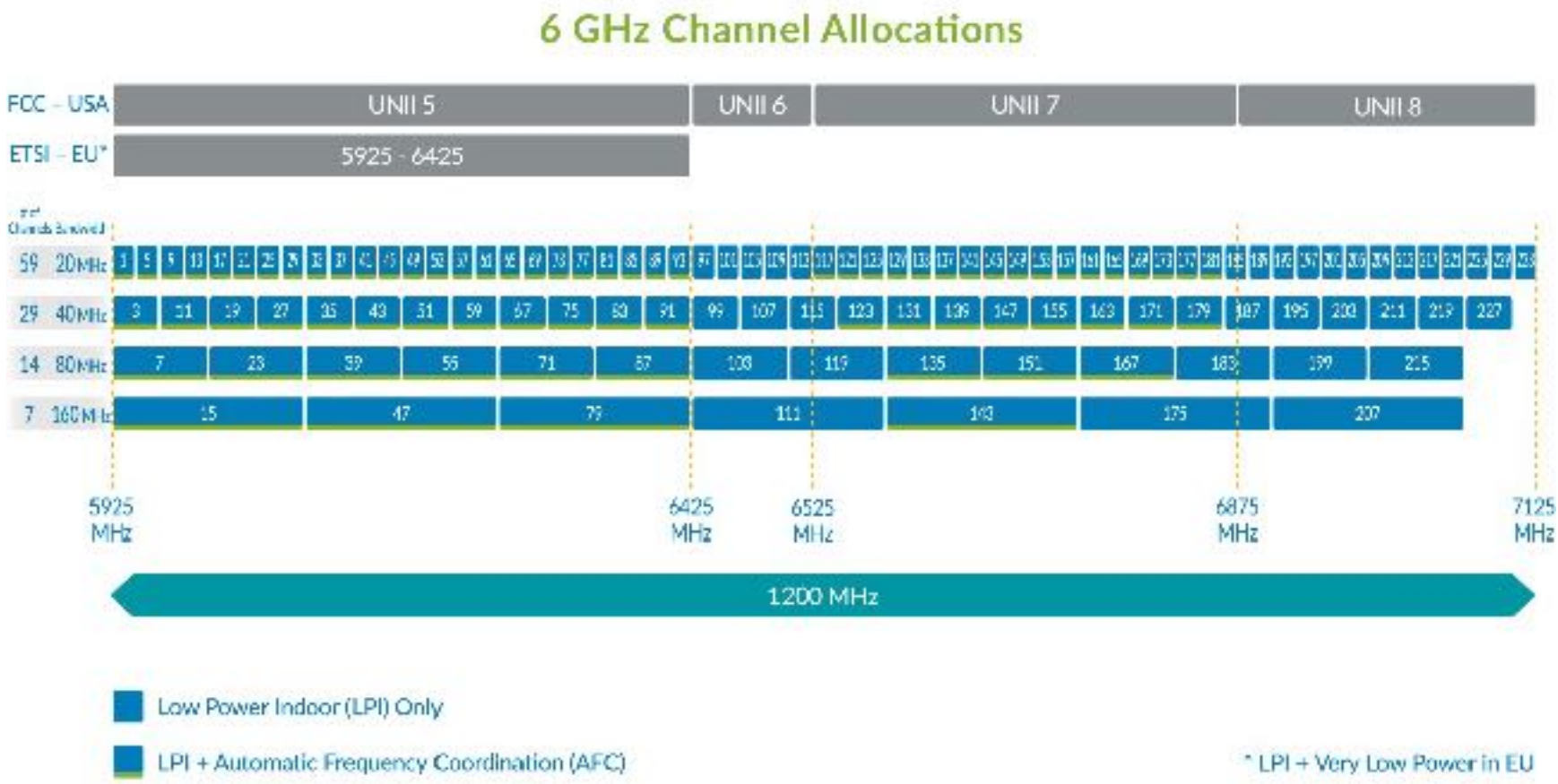
Wi-Fi Generations at a Glance

Rel. Year	1999	2007	2009	2013	2020	2023(?)
Freq. Band	2.4 GHz	2.4 GHz	2.4 + 5 GHz	5 GHz	2.4 + 5 + 6 GHz (6E)	2.4 + 5 + 6 GHz
Bandwidth	20 MHz	20 MHz	40 MHz	80 MHz, 160 MHz	80 MHz, 160 MHz	240 MHz, 320 MHz

Wi-Fi generations					
	Wi-Fi 4	Wi-Fi 5	Wi-Fi 6	Wi-Fi 6E	Wi-Fi 7 (expected)
Launch date	2007	2013	2019	2021	2024
IEEE standard	802.11n	802.11ac	802.11ax		802.11be
Max data rate	1.2 Gbps	3.5 Gbps	9.6 Gbps		46 Gbps
Bands	2.4 GHz and 5 GHz	5 GHz	2.4 GHz and 5 GHz	6 GHz	1–7.25 GHz (including 2.4 GHz, 5 GHz, 6 GHz bands)
Security	WPA 2	WPA 2	WPA 3		WPA3
Channel size	20, 40 MHz	20, 40, 80, 80+80, 160 MHz	20, 40, 80, 80+80, 160 MHz	20, 40, 80, 80+80, 160 MHz	Up to 320 MHz
Modulation	64-QAM OFDM	256-QAM OFDM	1024-QAM OFDMA		4096-QAM OFDMA (with extensions)
MIMO	4x4 MIMO	4x4 MIMO, DL MU-MIMO	8x8 UL/DL MU-MIMO		16x16 MU-MIMO

source: IEEE, Intel Corporation, Wi-Fi Alliance

New Wi-Fi 6E Channels

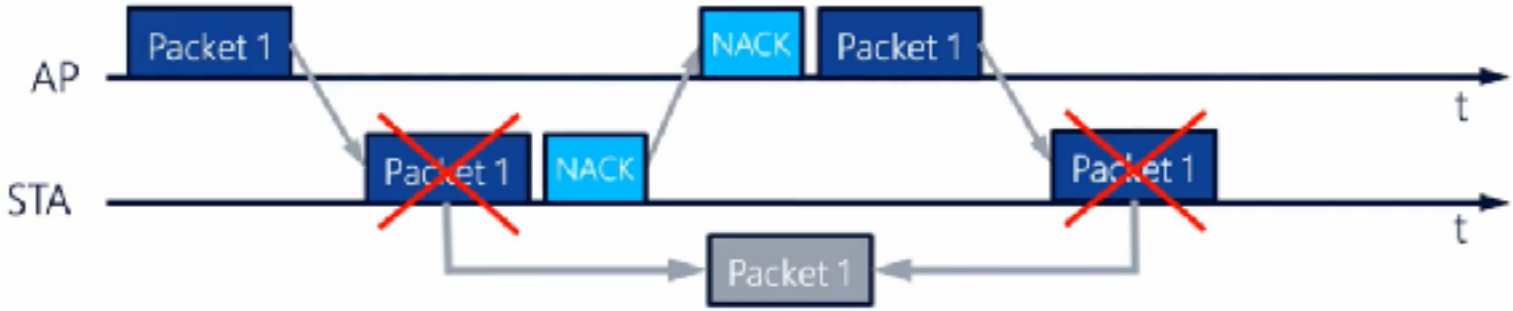


What is Wi-Fi 7 (IEEE802.11be) going to add?

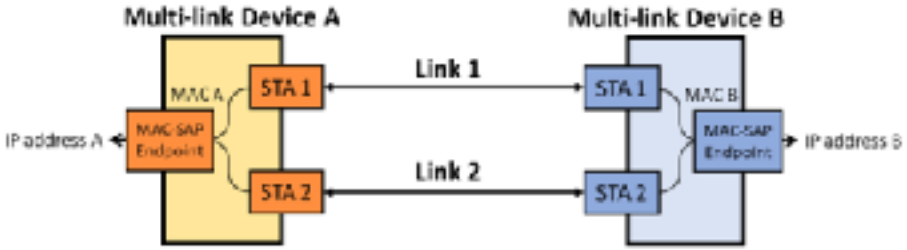
- Key upgrades from 802.11ax:
  1. 320 MHz
  2. Multiple RUs per STA
  3. 16 spatial streams
  4. 4K-QAM
- Disruptive new features in 802.11be:
  5. HARQ
  6. Multi-link operation
  7. Low-complexity AP coordination
  8. Advanced AP coordination

What is Hybrid ARQ (HARQ)?

- Boosting link adaptation via more efficient retransmission [25, 26]
  - Theoretical SNR gains in the order of 4 to 6 dB
  - Already discussed during 802.11ac and 802.11ax standardization
- Main concern: HARQ might not be robust against collisions caused by the unpredictable interference conditions in 802.11



What are Multi-(Band)-Links?

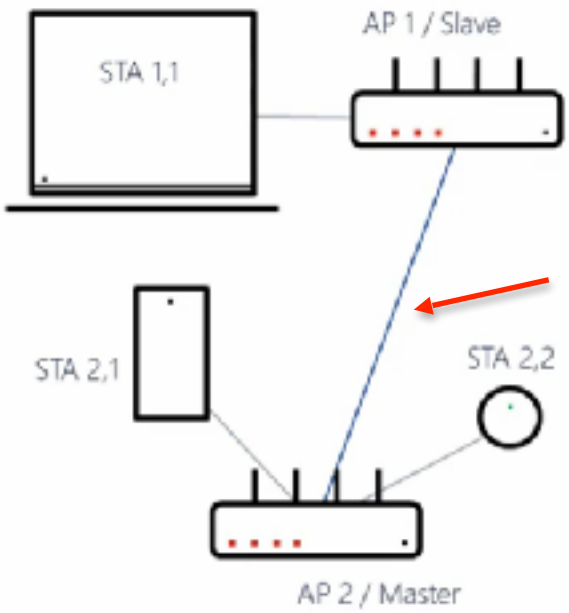


- Simultaneous use of 2.4 GHz, 5 GHz, and 6 GHz bands [16-18]:
  - Load balancing according to traffic needs
  - Data aggregation in different bands
  - Data transmission and reception separated in different bands
    - E.g., low bands for uplink and high bands for downlink
  - Control and data plane separated in different bands
    - E.g., low bands for control inf. and high bands for data tx/rx

New in Wi-Fi 7: Multi-AccessPoint-Coordination

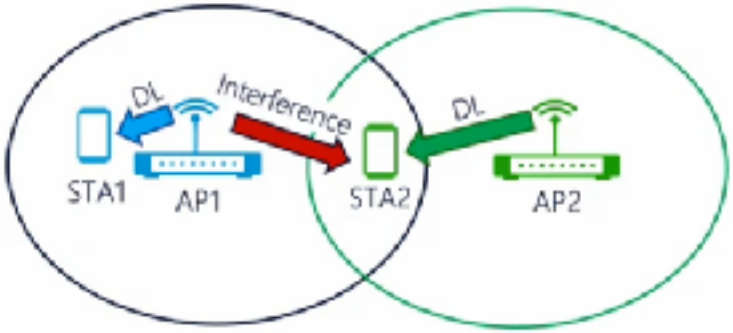
- Multiple near-by APs can coordinate (over the air) their time/frequency transmissions, so:
  - Avoid channel contention
  - Improve resource sharing
- Positives: Higher throughput & improved worst-case latency
- Negatives: Extra overheads / complexity

- Low-complexity multi-AP coordination
  - OFDMA; Spatial Reuse
- Advanced multi-AP coordination
  - Joint Beamforming; Joint Transmission

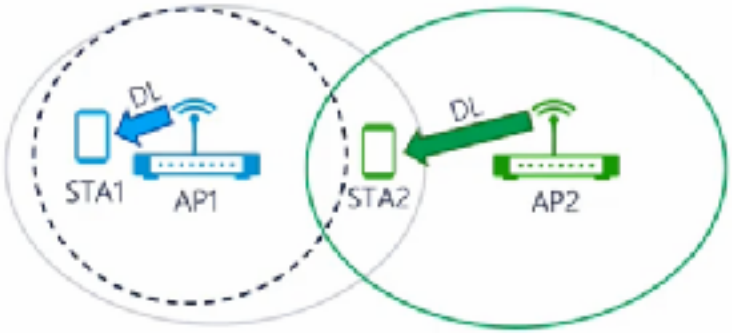


New in Wi-Fi 7: Multi-AccessPoint-Coordination

- Power coordination: Spatial reuse (SR) [21]
  - 802.11ax facilitates a more aggressive channel access
    - Channel access decisions solely based on measured power
  - 802.11be may allow APs to jointly schedule their transmissions
    - Objective: Enhance spatial reuse preventing "uncontrolled" collisions



Non-coordinated TX generates a collision



Coordinated TX: AP1 reduces its TX power to prevent the collision

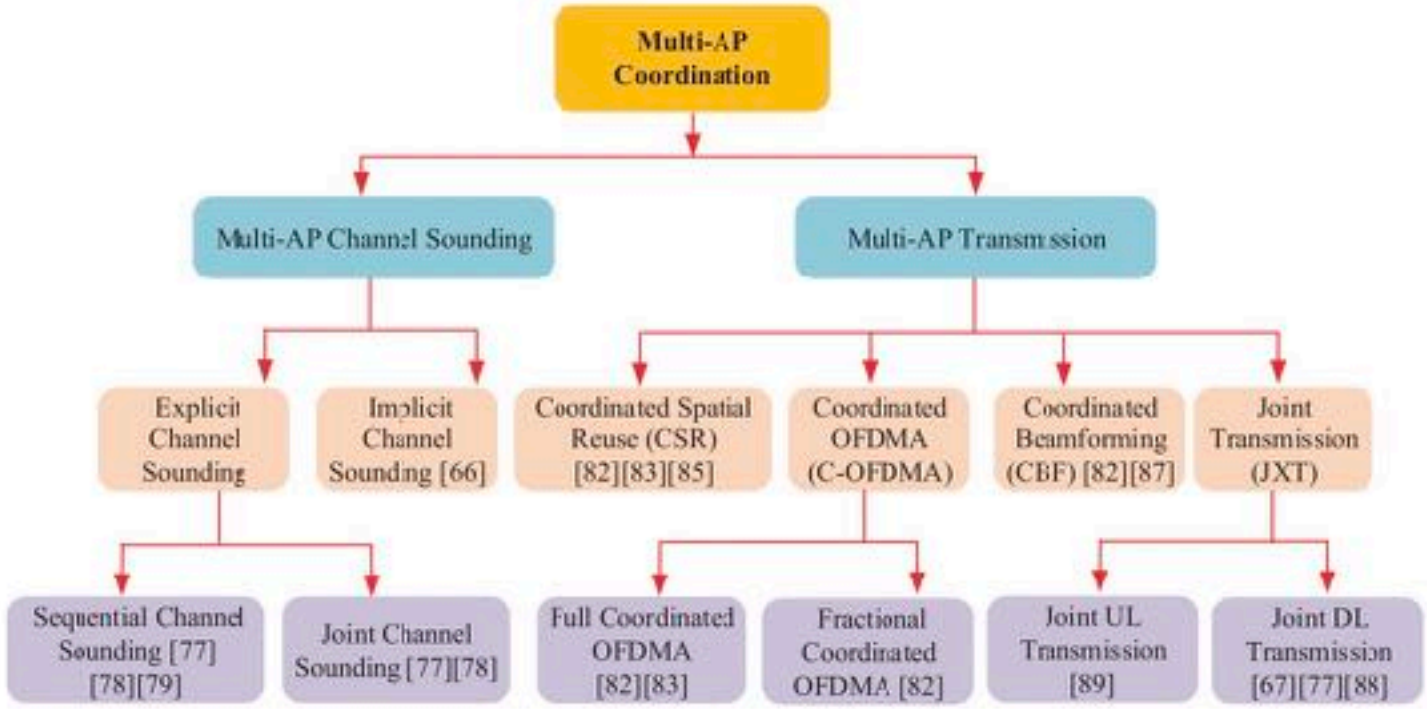


Fig. 15. Overview of the multi-AP coordination.

Wi-Fi 7 Standardisation Roadmap

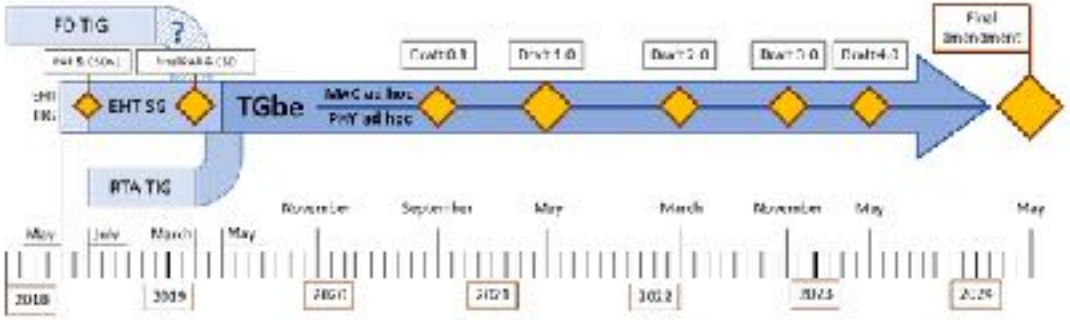
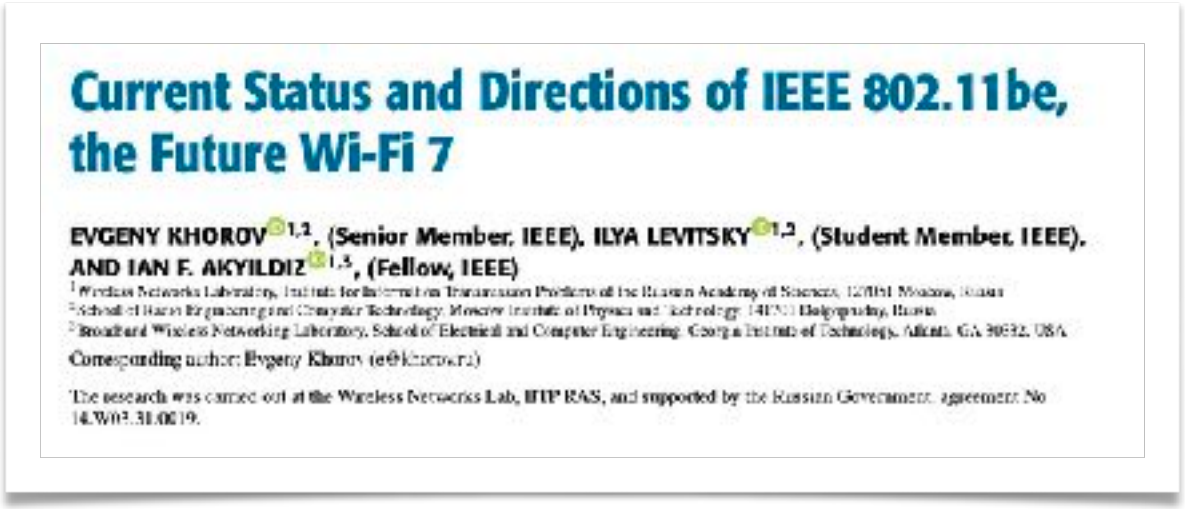


FIGURE 1. Timeline of the 11be standardization process.

References:



Current Status and Directions of IEEE 802.11be, the Future Wi-Fi 7

EVGENY KHOROV[1,2], (Senior Member, IEEE), ILYA LEVITSKY[1,2], (Student Member, IEEE), AND IAN F. AKYILDIZ[1,3], (Fellow, IEEE)

[1] Wireless Networks Laboratory, Institute for Information Transmission Problems of the Russian Academy of Sciences, 127051 Moscow, Russia
[2] School of Radio Engineering and Computer Technology, Moscow Institute of Physics and Technology, 141701 Dolgoprudny, Russia
[3] Broadband Wireless Networking Laboratory, School of Electrical and Computer Engineering, Georgia Institute of Technology, Atlanta, GA 30332, USA

Corresponding author: Evgeny Khorov (e@khorov.ru)

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IEEE 802.11be Wi-Fi 7: New Challenges and Opportunities

Cailian Deng, *Graduate Student Member, IEEE*, Xuming Fang, *Senior Member, IEEE*, Xiao Han, *Member, IEEE*, Xianbin Wang, *Fellow, IEEE*, Li Yan, *Member, IEEE*, Rong He, *Member, IEEE*, Yan Long, *Member, IEEE*, and Yuchen Guo