PCS3888 – 2023

ASPECTOS GERENCIAIS E ESTRATÉGICOS EM IOT

WIFI 6 & WIFI 7 p/IoT

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CONTEXTO

As demandas do mercado e as novas tecnologias impulsionam a inovação IEEE 802.11

- Demanda por *throughput*
  - ✓ Demanda exponencial contínua por taxa de transferência (802.11ax e 802.11ay, 802.11be)
  - ✓ A maior parte (50-80%, dependendo do país) dos dados móveis do mundo é transportada em dispositivos 802.11 (WiFi)

- Novos modelos/recursos de uso
  - Implantações densas (802.11ax), localização interna (802.11az),
  - Automotivo (IEEE Std 802.11p, V2X Próxima Geração), Internet das Coisas (802.11ah)
  - Aplicações de baixo consumo de energia (802.11ba)

- *Technical capabilities*
  - ✓ MIMO (IEEE Std 802.11n, 802.11ac, 802.11ay) e OFDMA (802.11ax)
  - ✓ Rádios 60 GHz (802.11ay)
- Mudanças na regulação
  - TV whitespaces (IEEE Std 802.11af), detecção de radar (IEEE Std 802.11h), 6GHz (802.11ax, 802.11be)
  - ✓ Regras de coexistência e desempenho de rádio (e.g., ETSI BRAN, ITU-R)

Fonte: D. Stanley. IEEE 802.11 Standards: Wi-Fi 6 and beyond.

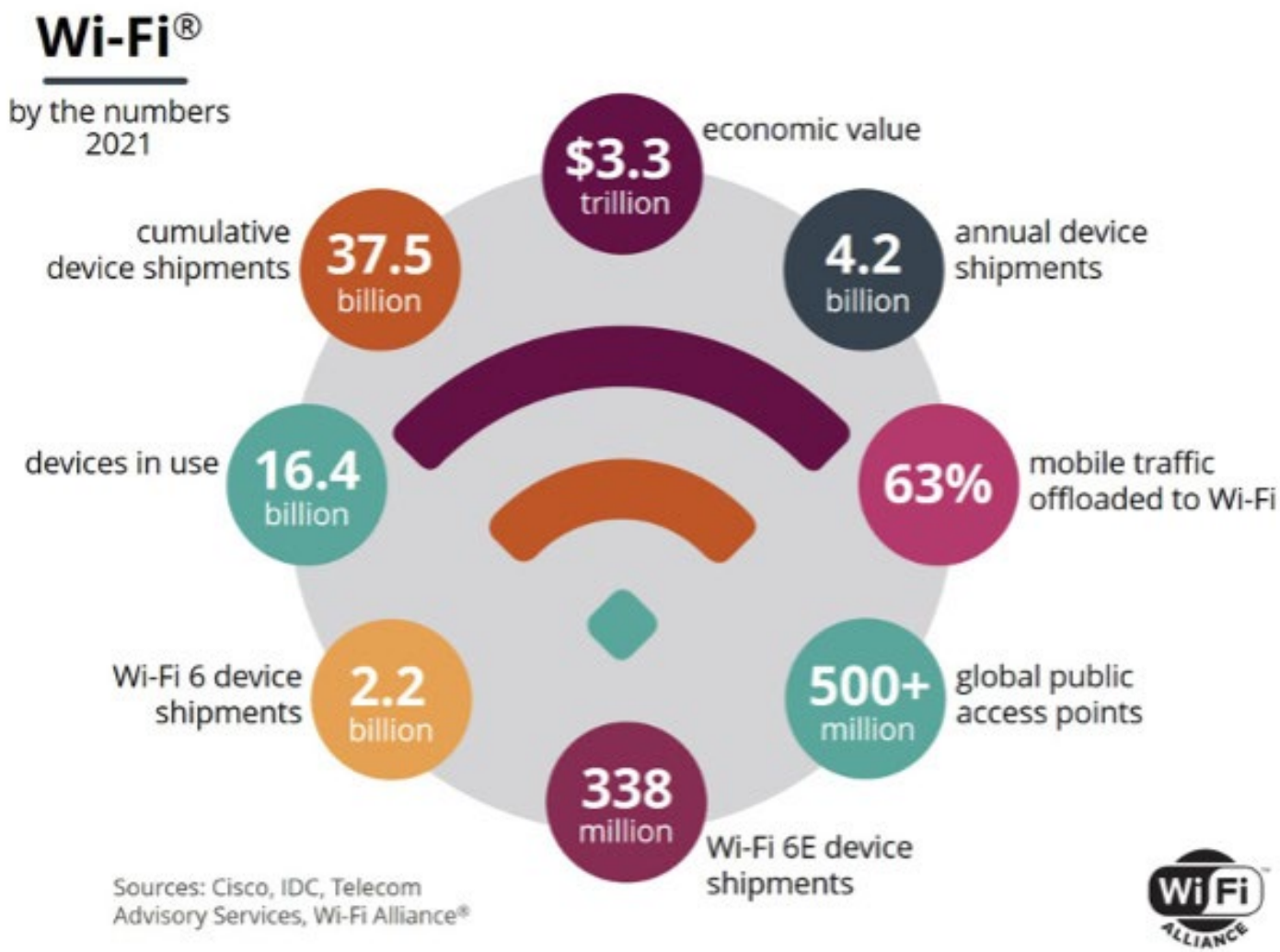
BUSCA DE MAIOR DESEMPENHO

1. MAIOR THROUGHPUT DE PICO
2. MENOR LATÊNCIA
3. MAIOR NÚMERO DE CLIENTES

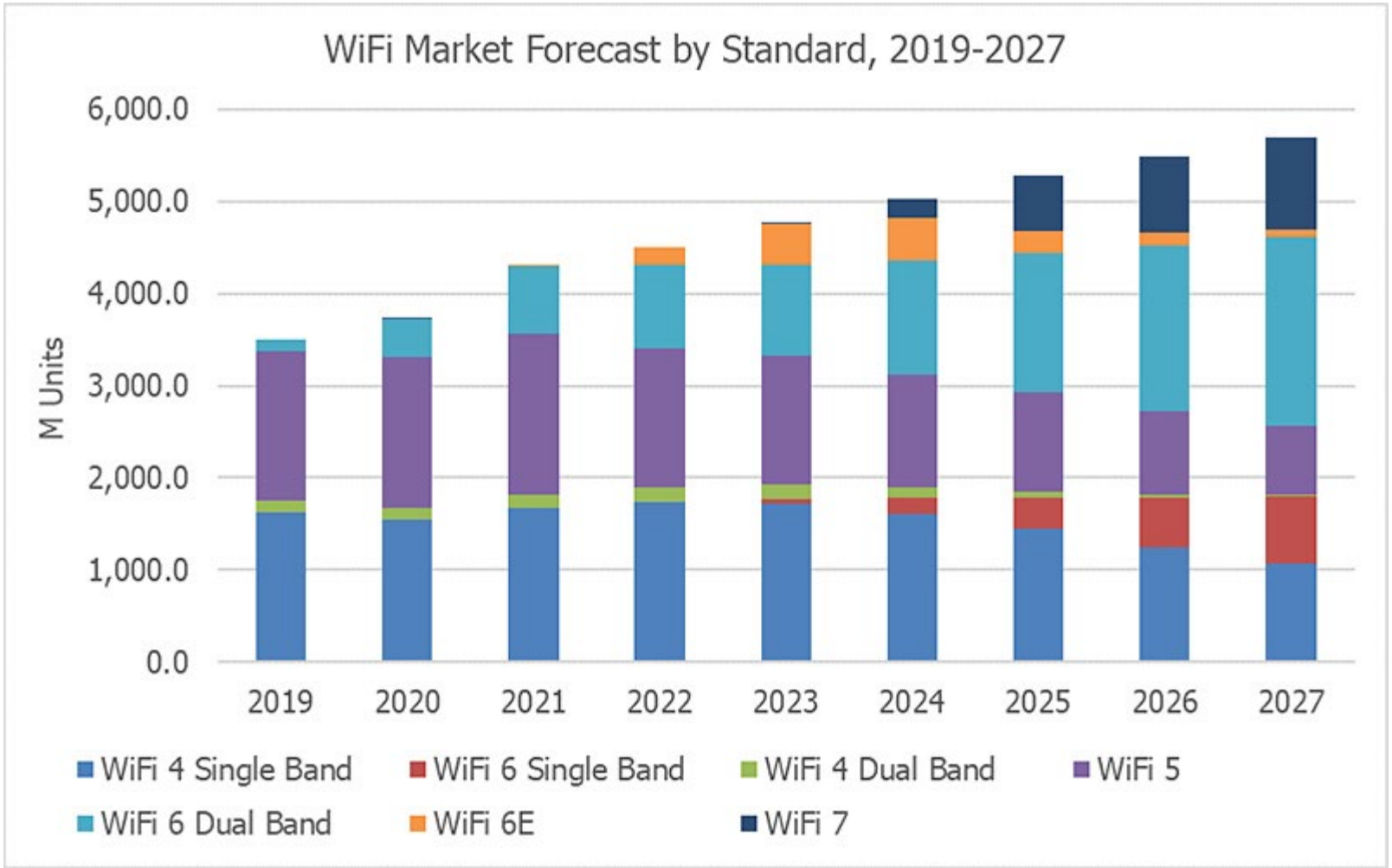
NOVOS OBJETIVOS NO WIFI6

- “EFICIÊNCIA NO USO DO AR”

- A tecnologia Wi-Fi 6 (802.11ax) visa um uso melhor e mais eficiente do meio de radiofrequência existente.
  - Taxas de dados mais altas não são o objetivo principal do Wi-Fi 6.
  - O objetivo é um gerenciamento de tráfego 802.11 melhor e mais eficiente.

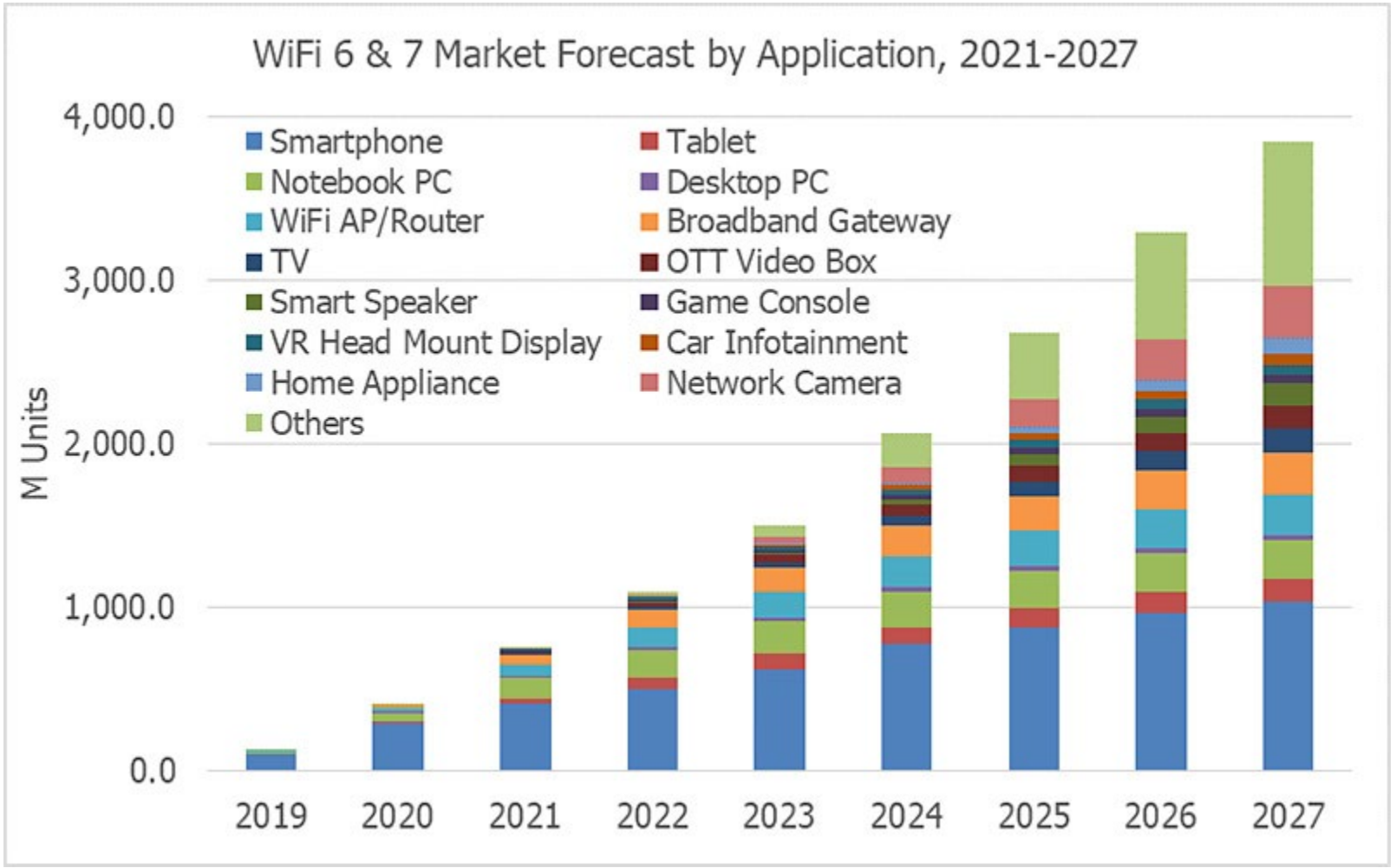

Wi-Fi®
by the numbers
2021
$3.3 trillion
economic value
37.5 billion
cumulative device shipments
4.2 billion
annual device shipments
16.4 billion
devices in use
63%
mobile traffic offloaded to Wi-Fi
2.2 billion
Wi-Fi 6 device shipments
500+ million
global public access points
338 million
Wi-Fi 6E device shipments
Sources: Cisco, IDC, Telecom Advisory Services, Wi-Fi Alliance®
Wi Fi ALLIANCE

MERCADO Wi-Fi



https://iotbusinessnews.com/2022/08/09/48205-new-wifi-6e-and-wifi-7-standards-market-and-applications/

MERCADO Wi-Fi 6 & 7



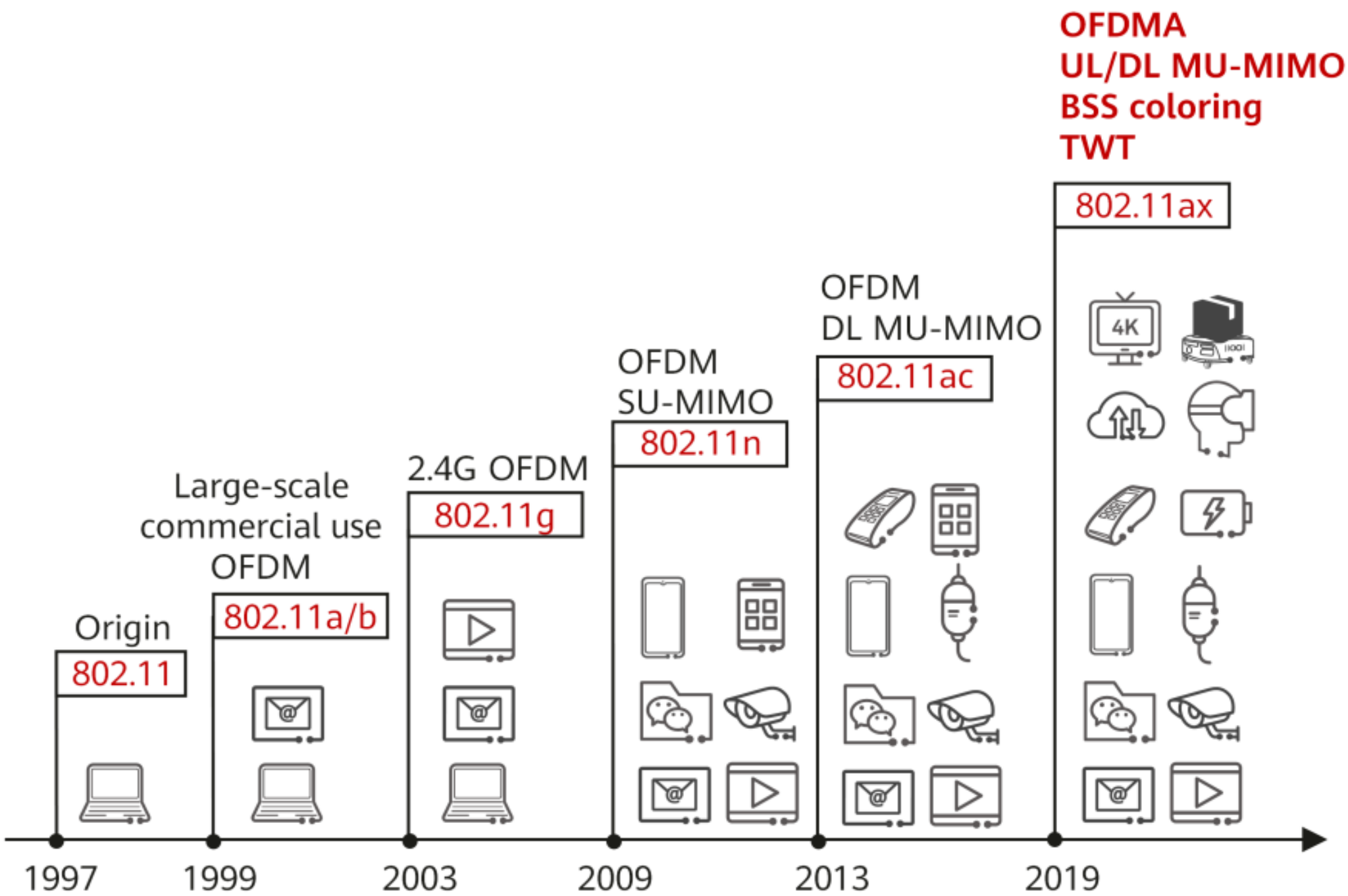

OFDMA
UL/DL MU-MIMO
BSS coloring
TWT
802.11ax
OFDM
DL MU-MIMO
802.11ac
OFDM
SU-MIMO
802.11n
2.4G OFDM
802.11g
Large-scale
commercial use
OFDM
802.11a/b
Origin
802.11
4K
1997
1999
2003
2009
2013
2019

Table 1-1 802.11 standards comparison

Standard Version	Frequency Band (GHz)	PHY Technology	Modulation	Spatial Streams	Channel Bandwidth (MHz)	Data Rate (Mbit/s)
802.11	2.4	IR, FHSS, and DSSS	-	-	20	1 and 2
802.11b	2.4	DSSS/CCK	-	-	20	5.5 and 11
802.11a	5	OFDM	64-QAM	-	20	6 - 54
802.11g	2.4	OFDM DSSS/CCK	64-QAM	-	20	1 - 54
802.11n	2.4 and 5	OFDM SU-MIMO	64-QAM	4	20 and 40	6 - 600
802.11ac	5	OFDM DL MU-MIMO	256-QAM	8	20, 40, 80, 160, and 80+80	6 - 6933.33
802.11ax	2.4, 5, and 6	OFDMA UL/DL MU-MIMO	1024-QAM	8	20, 40, 80, 160, and 80+80	6 - 9607.8

Wi-Fi 4 -> Wi-Fi 7


Standards Evolution
Wi-Fi 5
256 QAM
WPA2 Security
Wi-Fi 5
(Wave 2)
+ DL MU-MIMO (4x4)
Wi-Fi 7
4K QAM
320MHz Bandwidth
Multi-Link capabilities
Wi-Fi 4
64 QAM
Dual Band
Wi-Fi 6
1024 QAM
DL MU-MIMO (8x8)
OFDMA
WPA3 Security
Wi-Fi 6E
+ 6GHz operation
More 160MHz
Wi-Fi 6E
(Wave 2)
+ Uplink MU-MIMO
Spectrum Evolution
6GHz
5GHz
2.4GHz

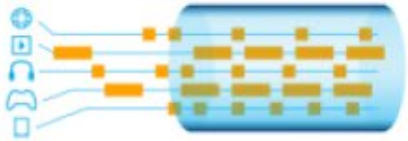
Wi-Fi 6

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

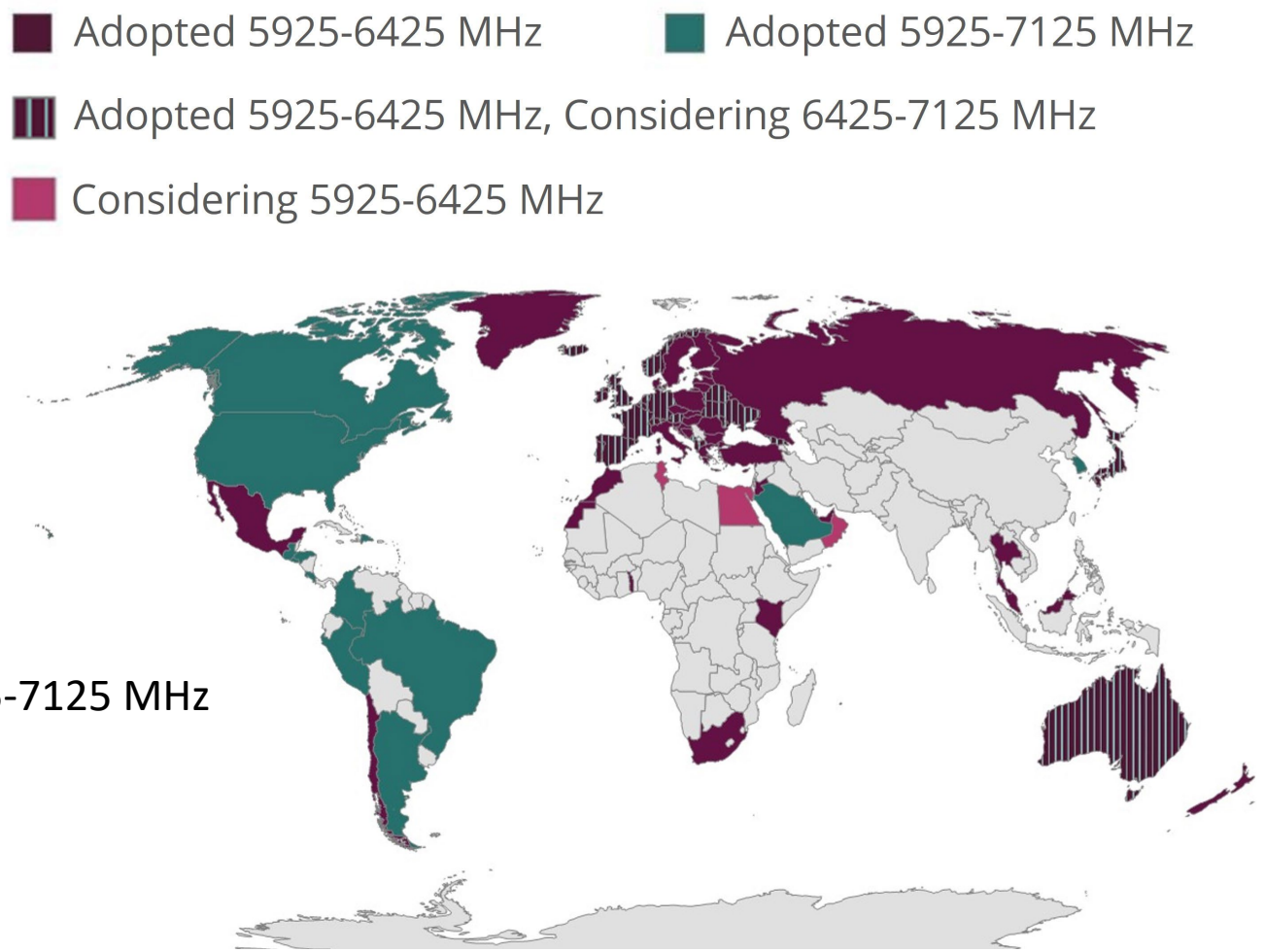
1024 QAM and support for optional 160 MHz channels enable clients and routers to deliver best-in-class Gigabit speeds for the office or home.

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

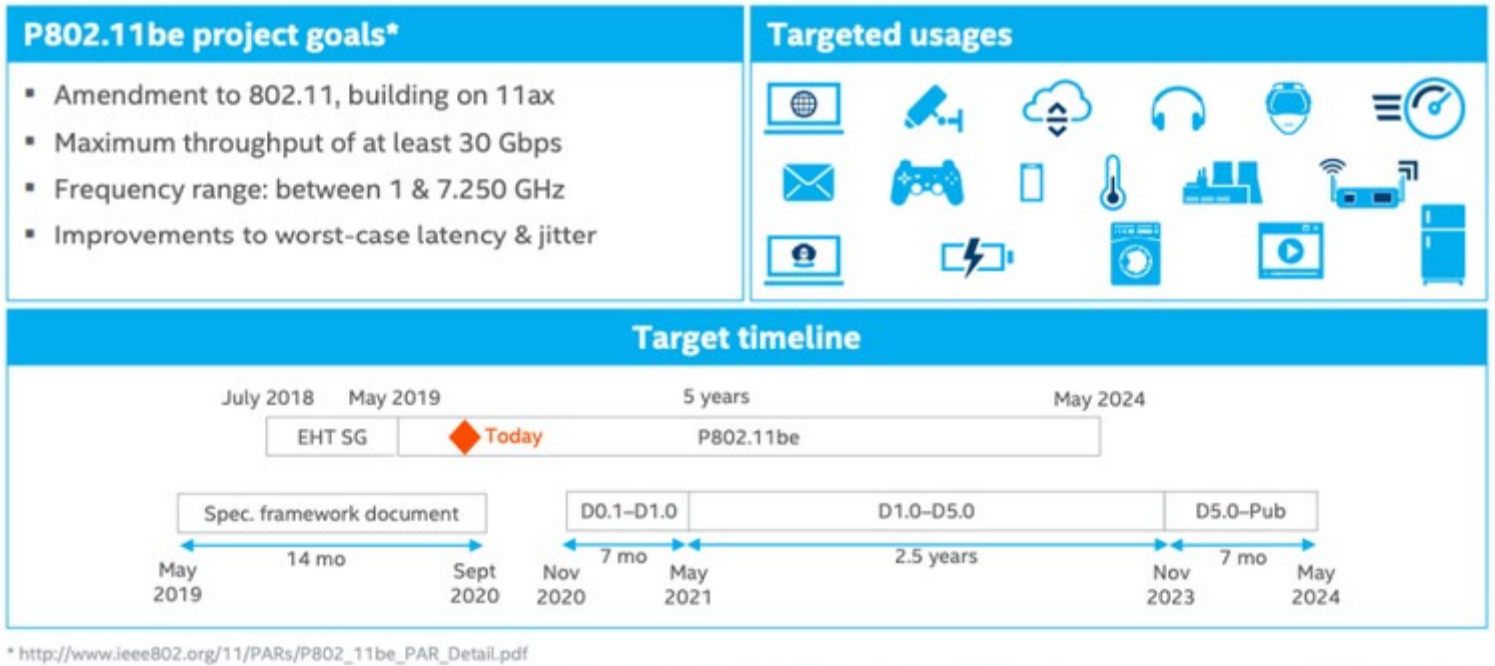
Wi-Fi 6E - 6 GHz



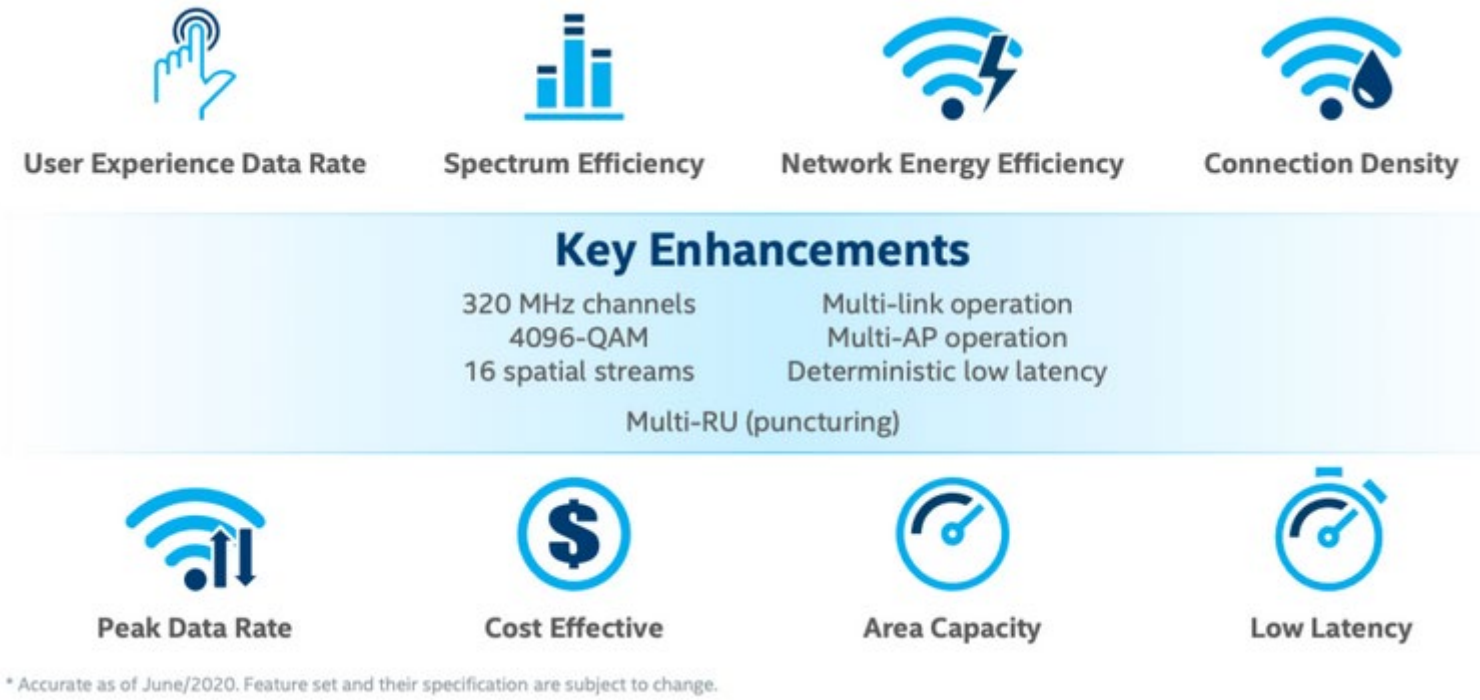
Brazil Adopted 5925-7125 MHz

https://www.wi-fi.org/countries-enabling-wi-fi-in-6-ghz-wi-fi-6e

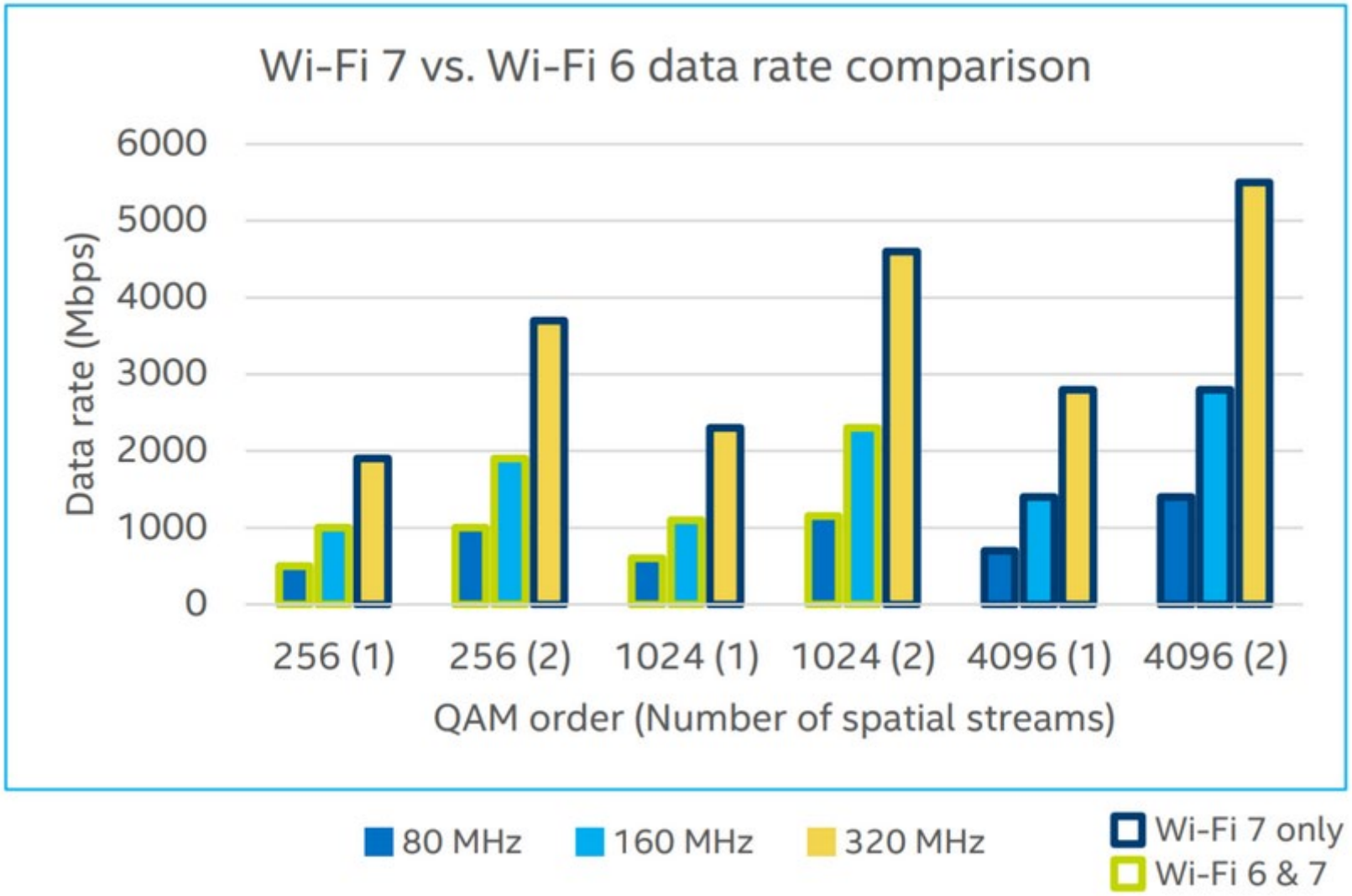
Wi-Fi 7


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
July 2018
May 2019
5 years
May 2024
EHT SG
Today
P802.11be
Spec. framework document
D0.1–D1.0
D1.0–D5.0
D5.0–Pub
May 2019
14 mo
Sept 2020
Nov 2020
7 mo
May 2021
2.5 years
Nov 2023
7 mo
May 2024
* http://www.ieee802.org/11/PARs/P802_11be_PAR_Detail.pdf

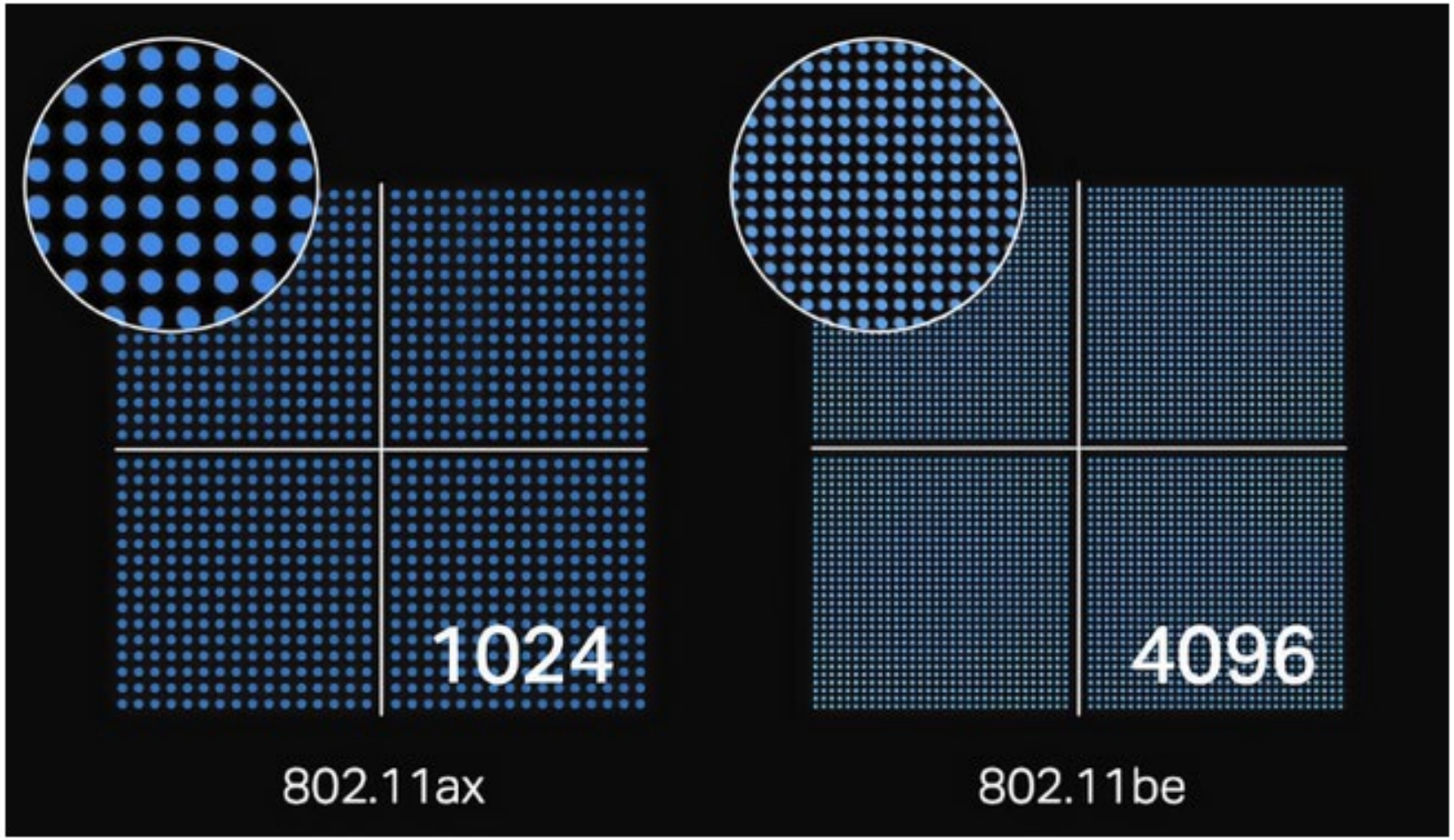
Wi-Fi 7


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.

Wi-Fi 6 vs Wi-Fi 7



QAM Wi-Fi 6 vs Wi-Fi 7



IEEE 802.11

Historic Wi-Fi Developments

The History of Wi-Fi

1971 The Presentation

First public demonstration of ALOHAnet, a wireless packet data network operating on UHF (Ultra High Frequency) radio waves connecting 7 computers spread across four islands without phone lines.

1973 Network Standard

- Initiated by Bob Metcalfe of Xerox Palo Alto Research Center
- Memo about Ethernet network standard for connecting computers.
- This was the beginning of a central standard for connecting computers rather than separate proprietary solutions.
- Set the stage for a similar wireless standard.

1985 Open Network Use

- Federal Communications Commission, America's Telecom regulator, opens the ISM (Industrial, Science, and Medicine) Band of the Wireless spectrum for use in communications without a government license.
- The frequencies include 900MHz, 2.4GHz, and 5.8 GHz, which are still commonly used today.

1990 The Father of Wi-Fi

The IEEE 802.11 Working Group for Wireless LANs is founded. It is led by Vic Hayes who is sometimes known as the "Father of Wi-Fi".

1993 Public Hotspots

The concept of a public access Local Wireless Network is introduced by Henrik Sjödin. The term hotspot wouldn't be coined until 1998.

1997

802.11 - 2 Mbps

Source: Mercku. Wi-Fi: The Definitive Guide

Historic Wi-Fi Developments

1999 — 802.11b – 11 Mbps

The Wi-Fi Alliance

The Wi-Fi Alliance is founded as non-profit trade association working for universal compatibility and quality user experience.

2003 — 802.11g – 108 Mbps

Spectrum Increases

- The World Radio Conference allocates the 5GHz band of radio spectrum for wireless access devices.
- The Calypso Wireless C1250i phone is announced as the first phone to allow both cell phone and Wi-Fi VoIP calls.

2005 — 802.11e – 108 Mbps

100 Million Chipsets

Wi-Fi chipset shipments top 100 million annually.

2009 — 802.11n – 600 Mbps

The 1 Billionth Chipset

The 1 billionth Wi-Fi chipset is sold.

2010

1 Million Hotspots

1,000,000 Wi-Fi hotspots are estimated to be active worldwide.

2014 — 802.11ac – 1.7 Gbps

802.11AC Router

D-Link releases the first portable 802.11ac router.

2015

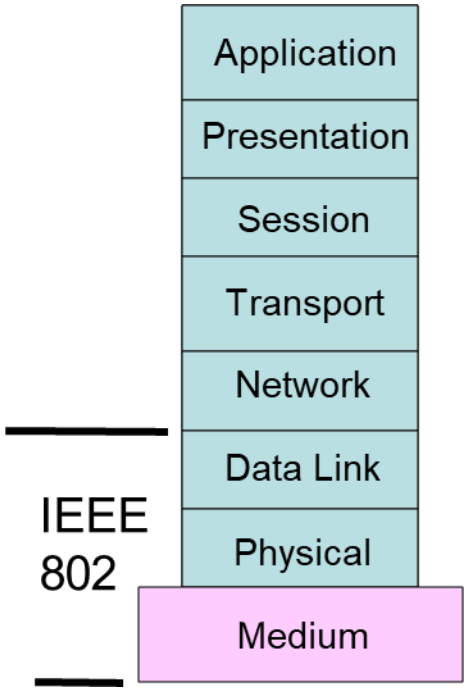
70,000,000 Hotspots

70,000,000 Wi-Fi hotspots are estimated to be active worldwide.

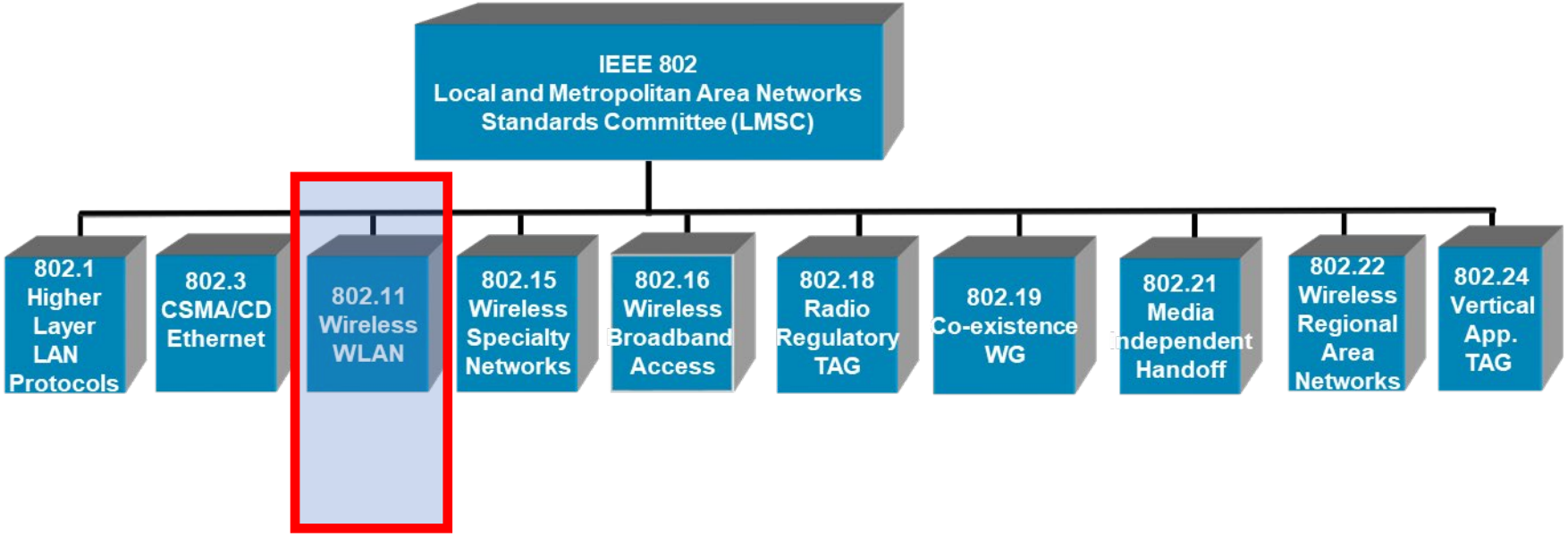
2019 — 802.11ax – 3.5 Gbps

Source: Mercku. Wi-Fi: The Definitive Guide

IEEE 802


Application
Presentation
Session
Transport
Network
Data Link
Physical
Medium
IEEE
802

IEEE 802.11 Working Group

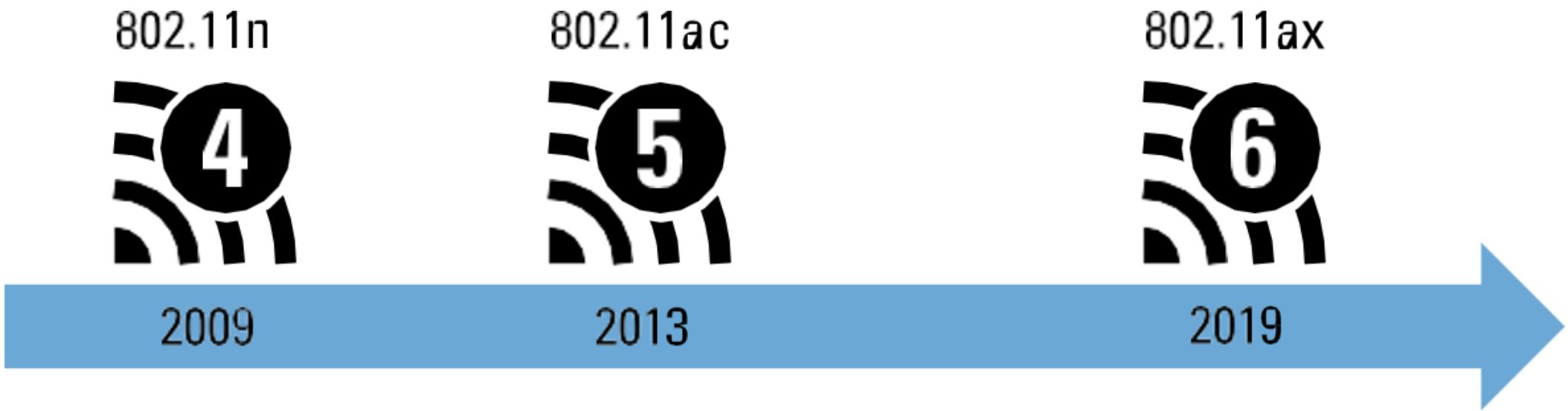


Iniciativas IEEE 802.11

- ✓802.11ax – Increased throughput in 2.4, 5 (and 6) GHz bands. Increased efficiency.
- ✓802.11ay – Support for 20 Gbps in 60 GHz band
- ✓802.11be – Extremely High Throughput

- ✓802.11az – 2nd generation positioning features
- ✓802.11ba – Wake up radio. Low power IoT applications.
- ✓802.11bb – Light Communications
- ✓802.11bc – Enhanced Broadcast Service
- ✓802.11bd – Enhancements for Next Generation V2X

Gerações WiFi - 2019



source: https://www.wi-fi.org/discover-wi-fi/wi-fi-6

1999
802.11b was released / “Wi-Fi 1”

2003
802.11a was released / “Wi-Fi 2”

2003
802.11g was released / “Wi-Fi 3”

2009
802.11n was released / “Wi-Fi 4”

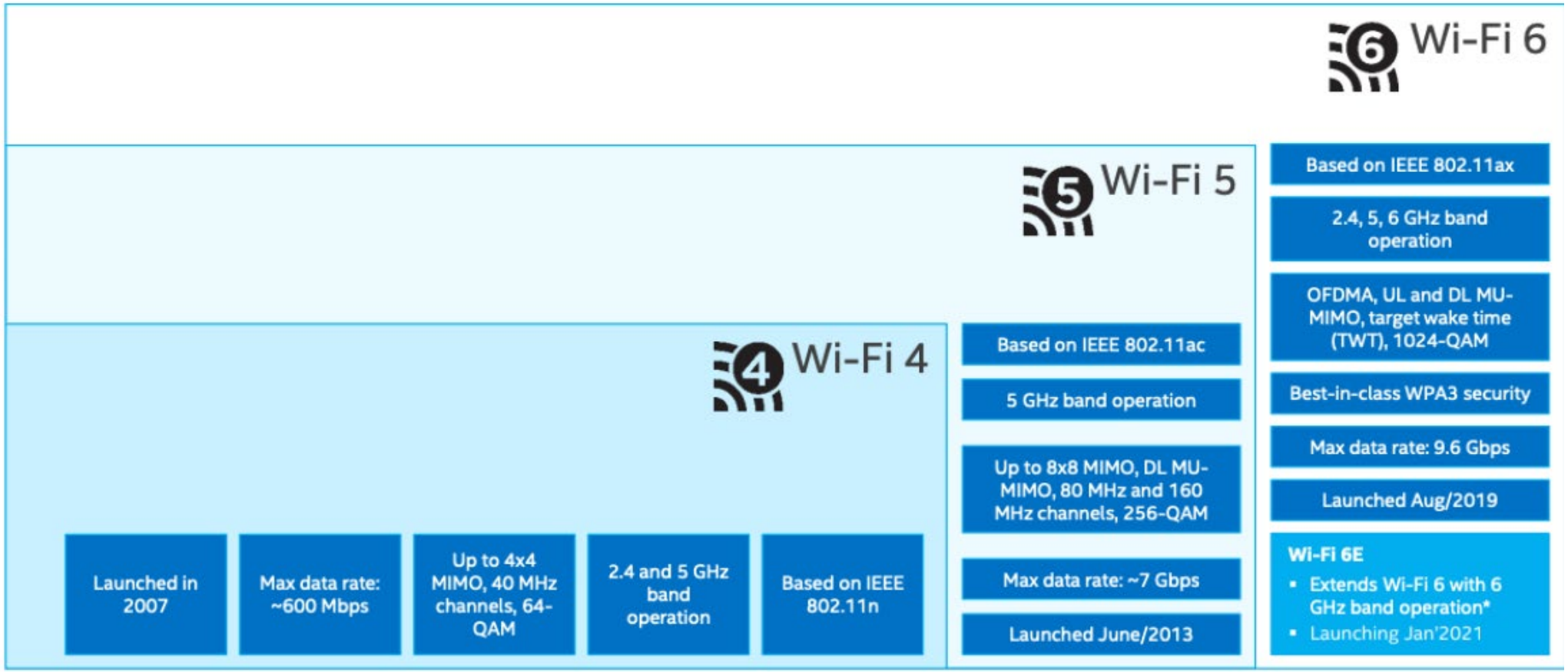
2014
802.11ac was released / “Wi-Fi 5”

2019
802.11ax was released / “Wi-Fi 6”

2020
6GHz Wi-Fi was released / “Wi-Fi 6E”

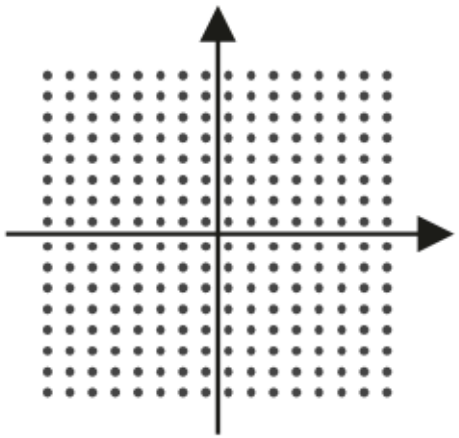
Est. 2024
802.11be estimated release/ “Wi-Fi 7”

Wi-Fi 4 -> Wi-Fi 6


Wi-Fi 6
Wi-Fi 5
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
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
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

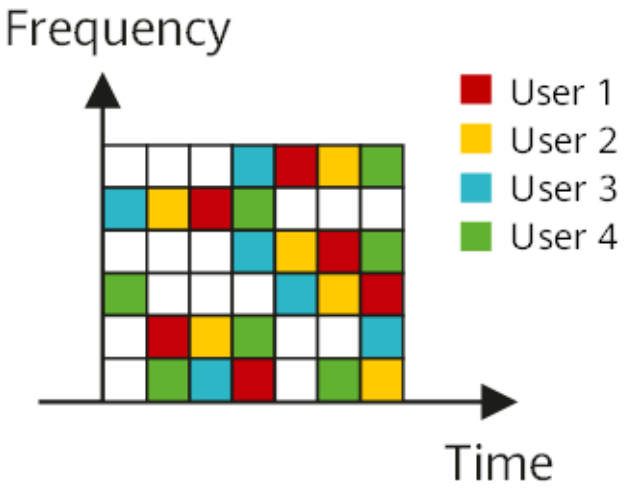
Wi-Fi 6

High bandwidth



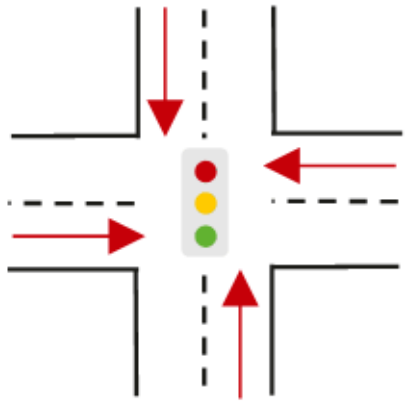
1024-QAM
8x8 MU-MIMO

Low latency



OFDMA
UL/DL MU-MIMO

High concurrency

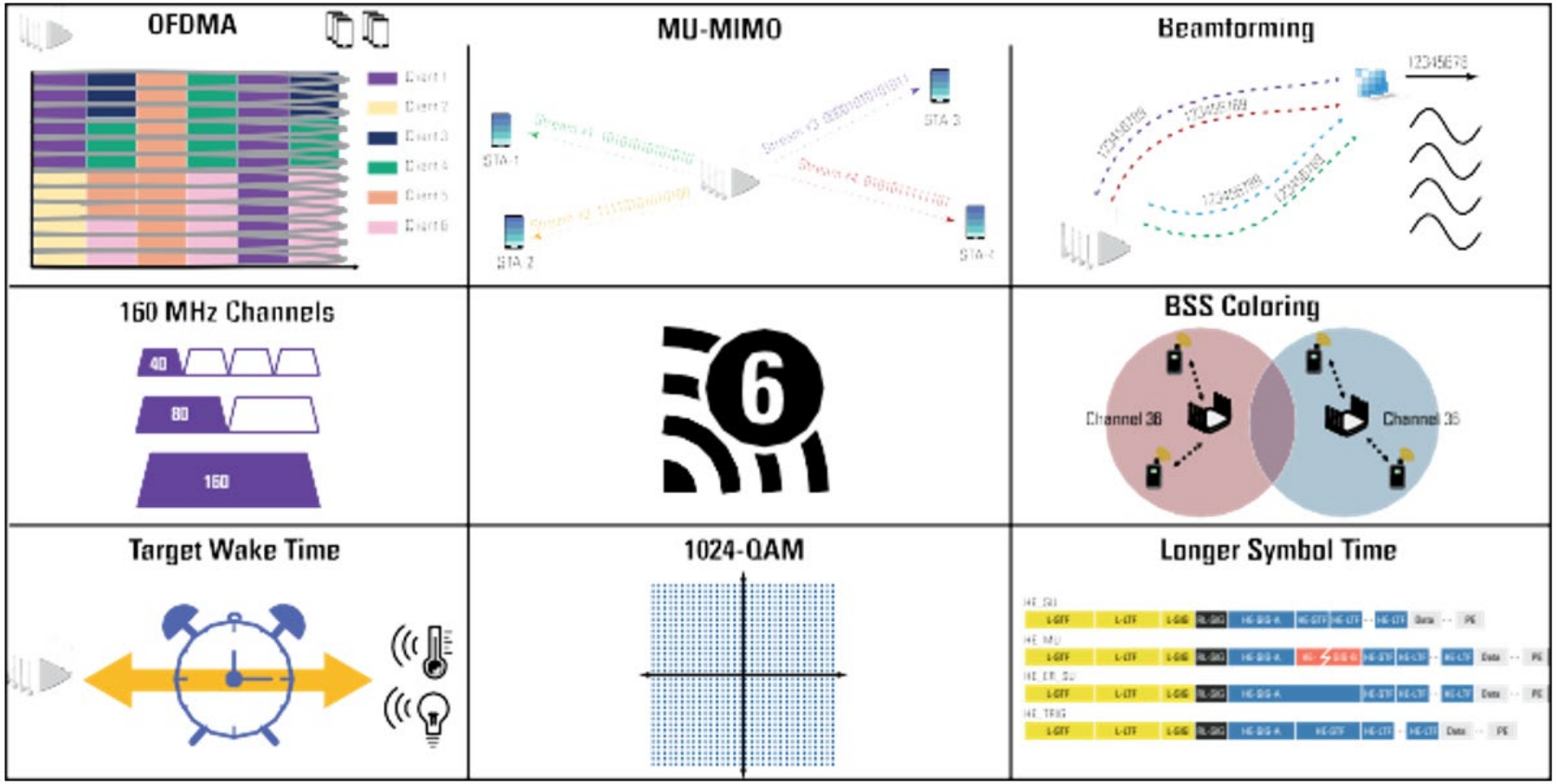


OFDMA
Spatial reuse &
BSS coloring

Lower power consumption

TWT

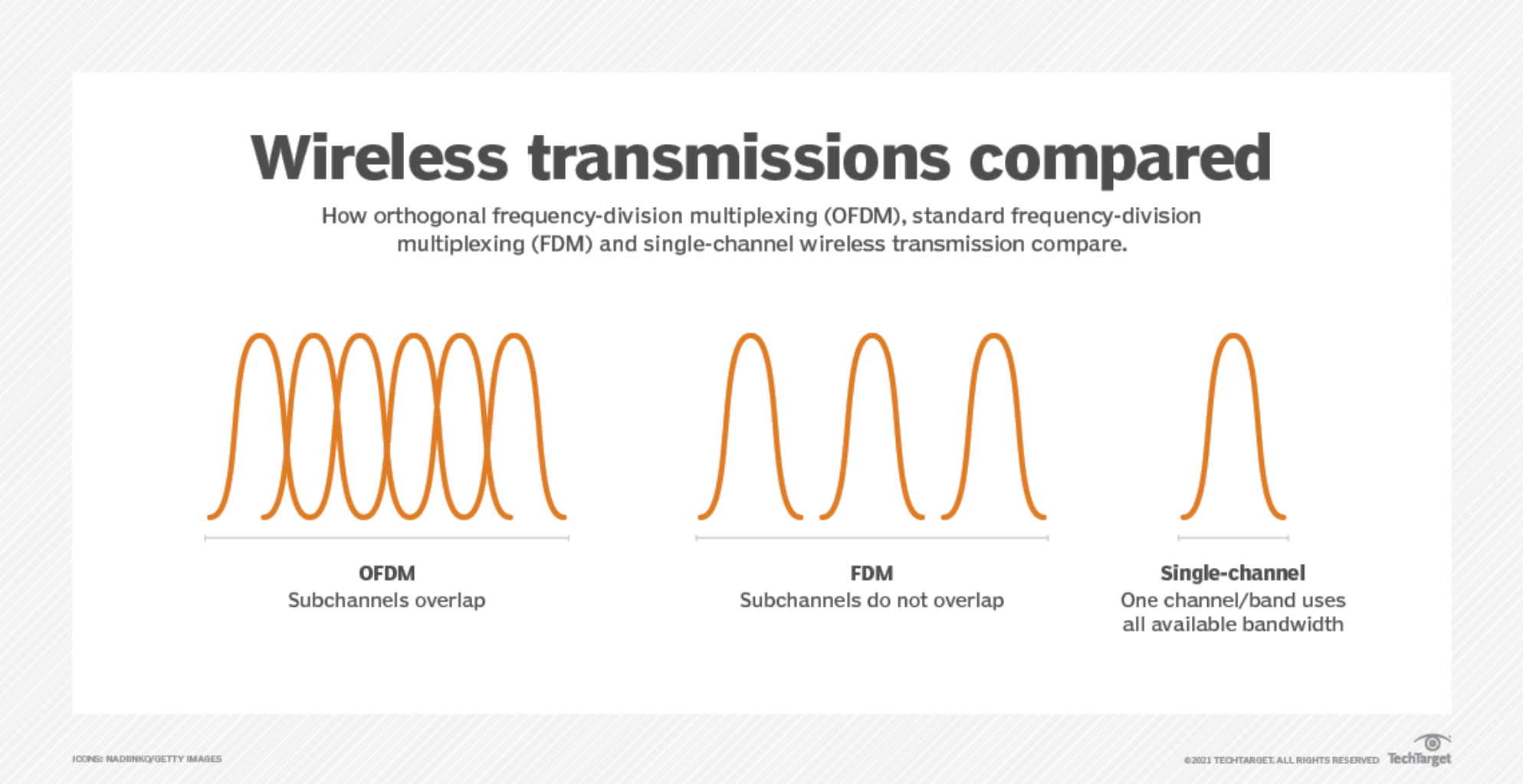
WIFI6


OFDMA
MU-MIMO
STA 1
STA 2
STA 3
Beamforming
160 MHz Channels
40
80
160
6
BSS Coloring
Channel 36
Channel 36
Target Wake Time
1024-QAM
Longer Symbol Time

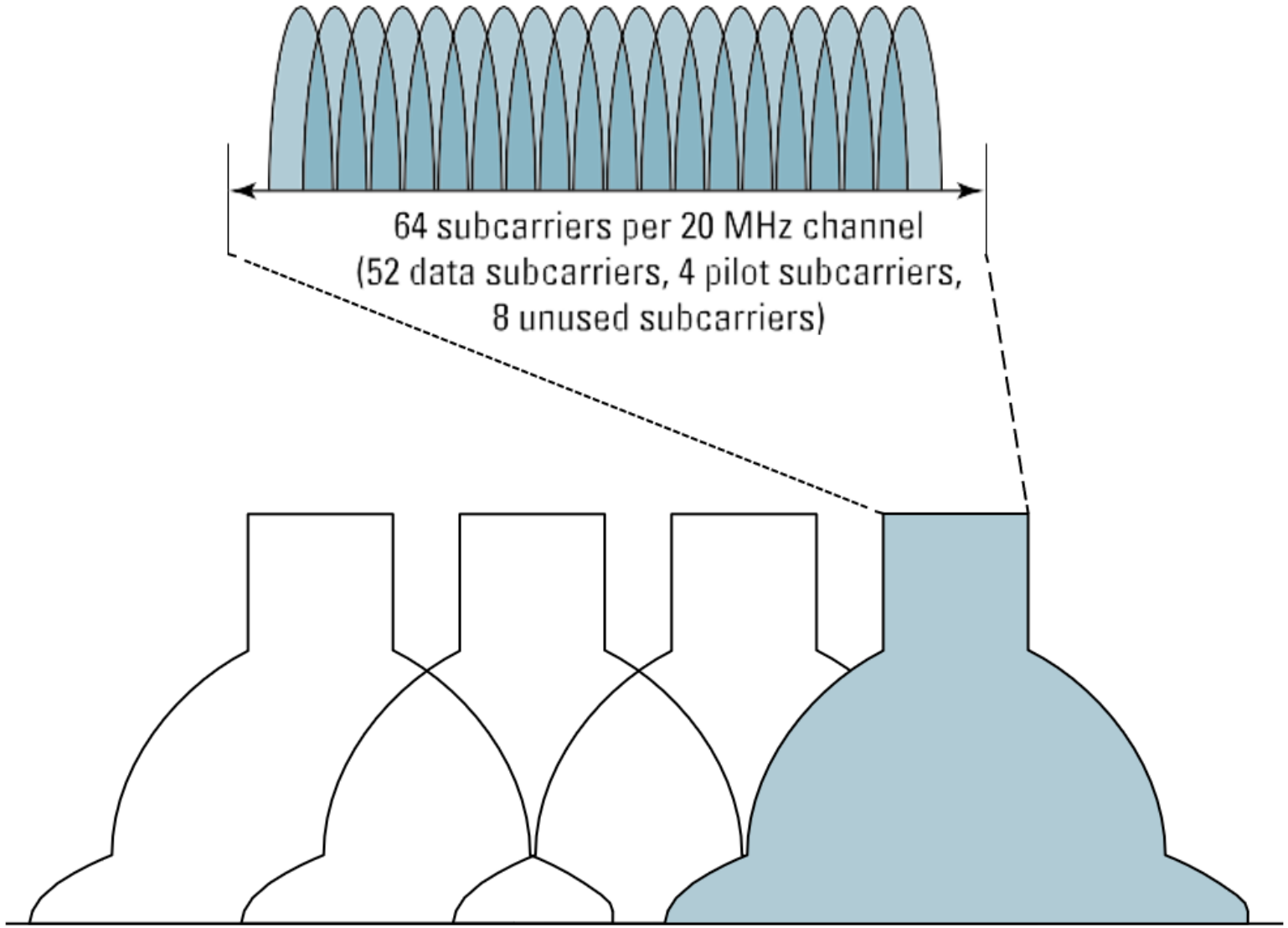
	802.11n (Wi-Fi 4)	802.11ac (Wi-Fi 5)	802.11ax (Wi-Fi 6)
Frequency bands	2.4 GHz and 5 GHz	5 GHz only	2.4 GHZ, 5 GHz, 6 GHz
Channel size (MHz)	20, 40	20, 40, 80, 80 + 80, and 160	20, 40, 80, 80 + 80, and 160
Frequency multiplexing	OFDM	OFDM	OFDM and OFDMA
Subcarrier spacing (KHz)	312.5	312.5	78.125
OFDM symbol time (µs)	3.2	3.2	12.8
Guard interval (µs)	.04 or .08	.04 or .08	.08, 1.6, or 3.2

	802.11n (Wi-Fi 4)	802.11ac (Wi-Fi 5)	802.11ax (Wi-Fi 6)
Total symbol time (µs)	3.6 or 4.0	3.6 or 4.0	13.6, 14.4, or 16.0
Modulation	BPSK, QPSK, 16-QAM, 64-QAM	BPSK, QPSK, 16-QAM, 64-QAM, 256-QAM	BPSK, QPSK, 16-QAM, 64-QAM, 256-QAM, 1024-QAM
MU-MIMO	N/A	DL	DL and UL
OFDMA	N/A	N/A	DL and UL

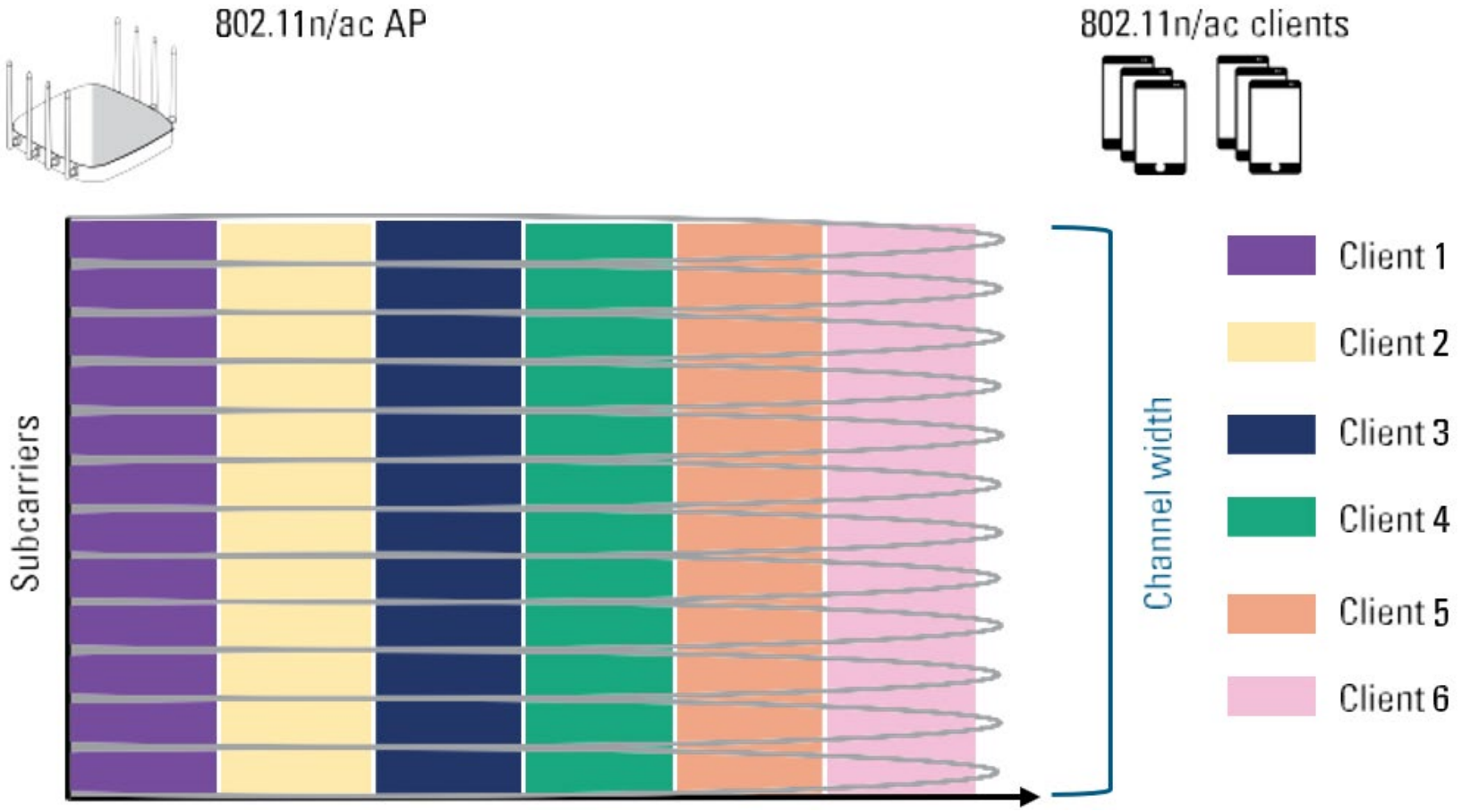
OFDM VS FDM


Wireless transmissions compared
How orthogonal frequency-division multiplexing (OFDM), standard frequency-division multiplexing (FDM) and single-channel wireless transmission compare.
OFDM
Subchannels overlap
FDM
Subchannels do not overlap
Single-channel
One channel/band uses all available bandwidth
ICONS: NADIINKO/GETTY IMAGES
©2021 TECHTARGET. ALL RIGHTS RESERVED
TechTarget

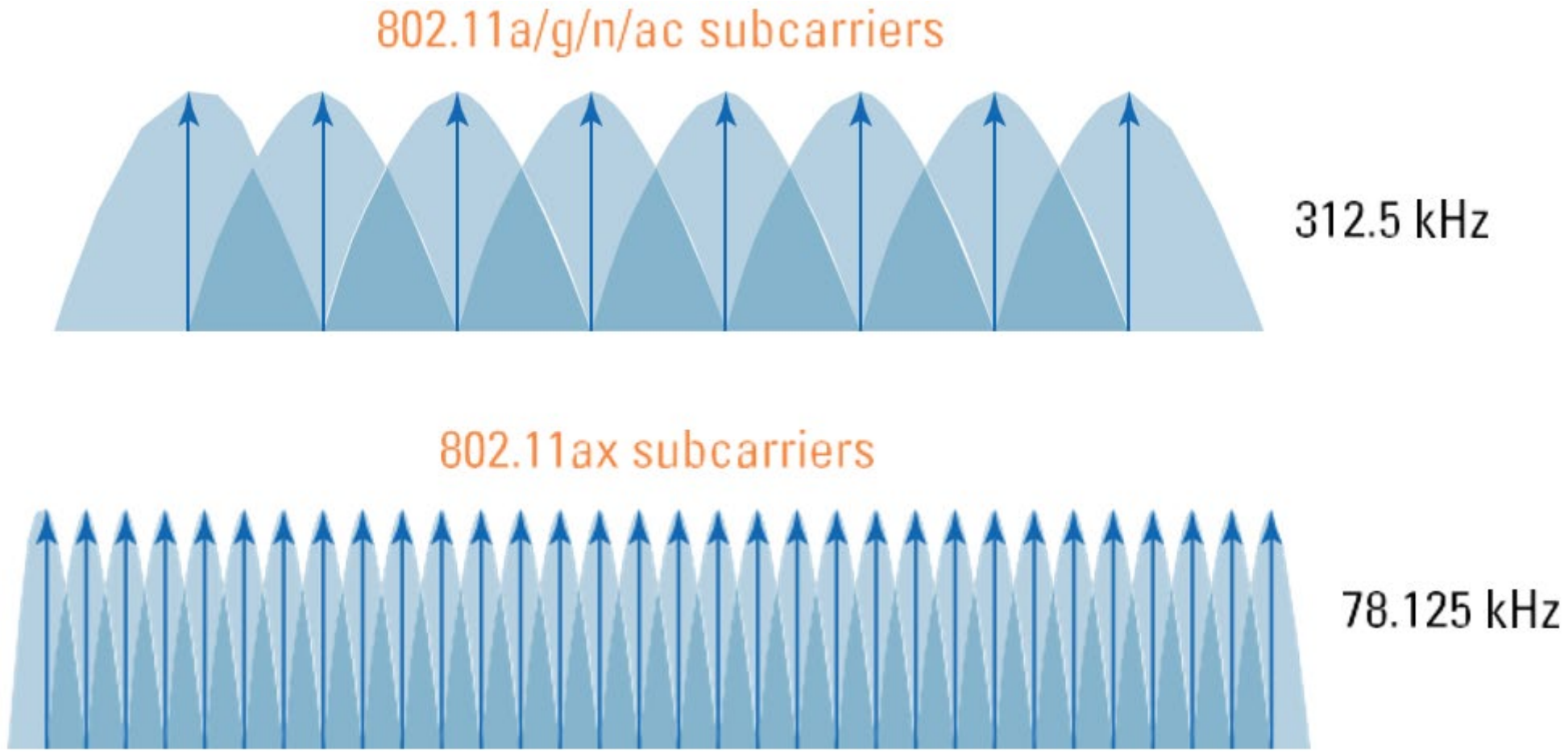
802.11n/ac 20 MHz channel – OFDM subcarriers



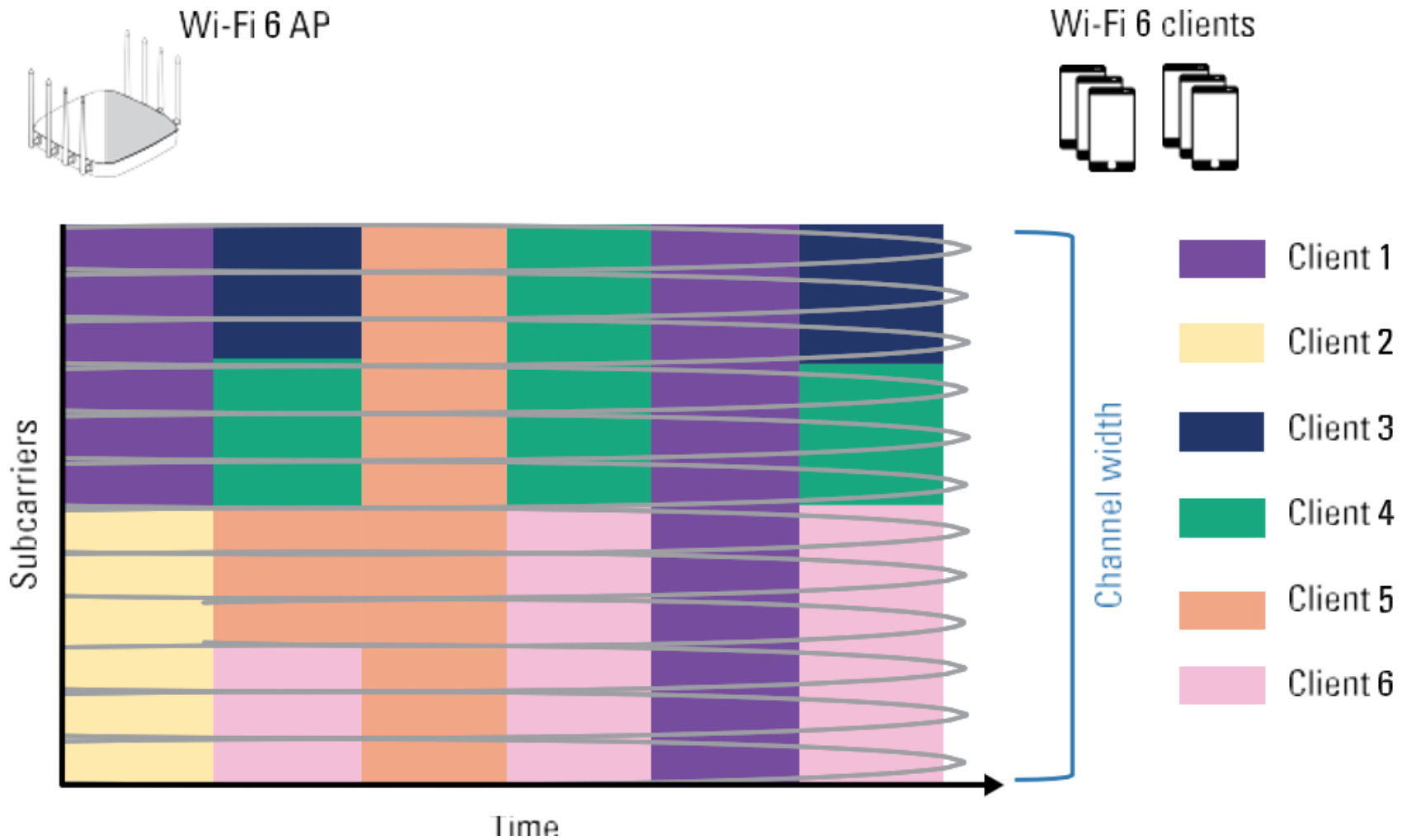
TRANSMISSÃO OFDM



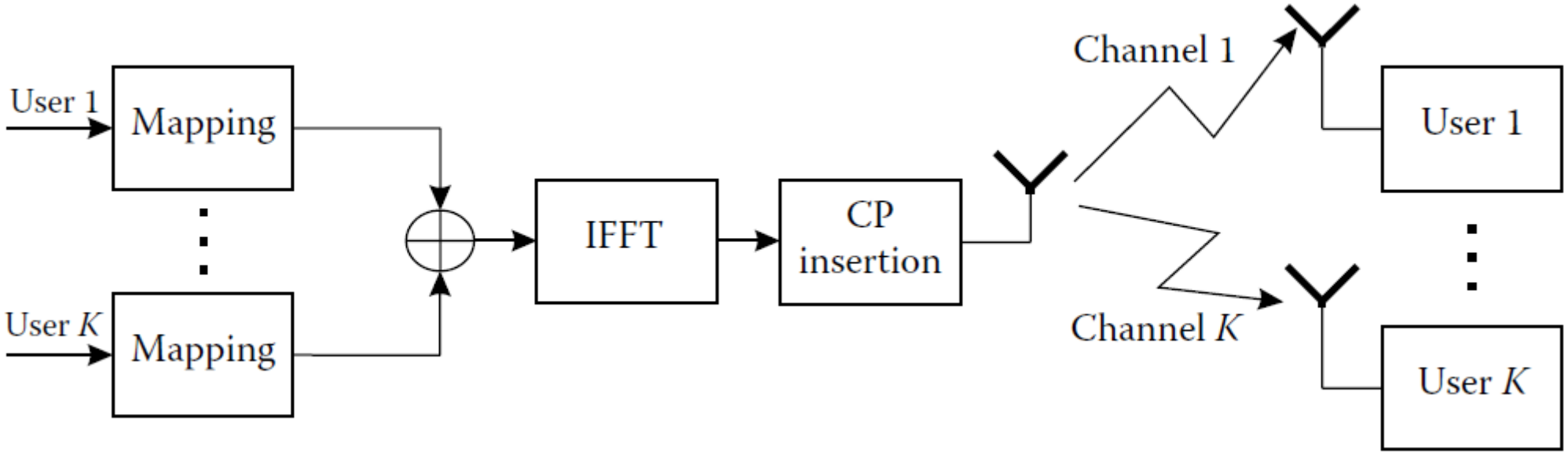
ESPAÇAMENTO ENTRE SUBPORTADORAS



TRANSMISSÃO OFDMA

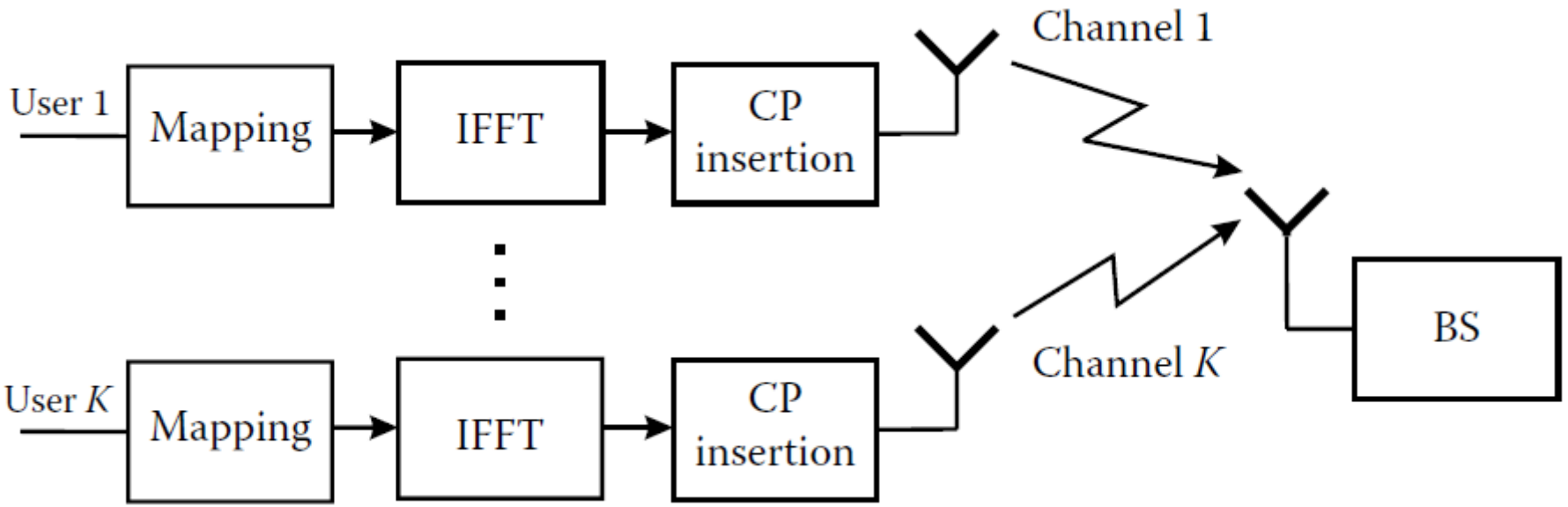


Block diagram of OFDMA downlink transmission



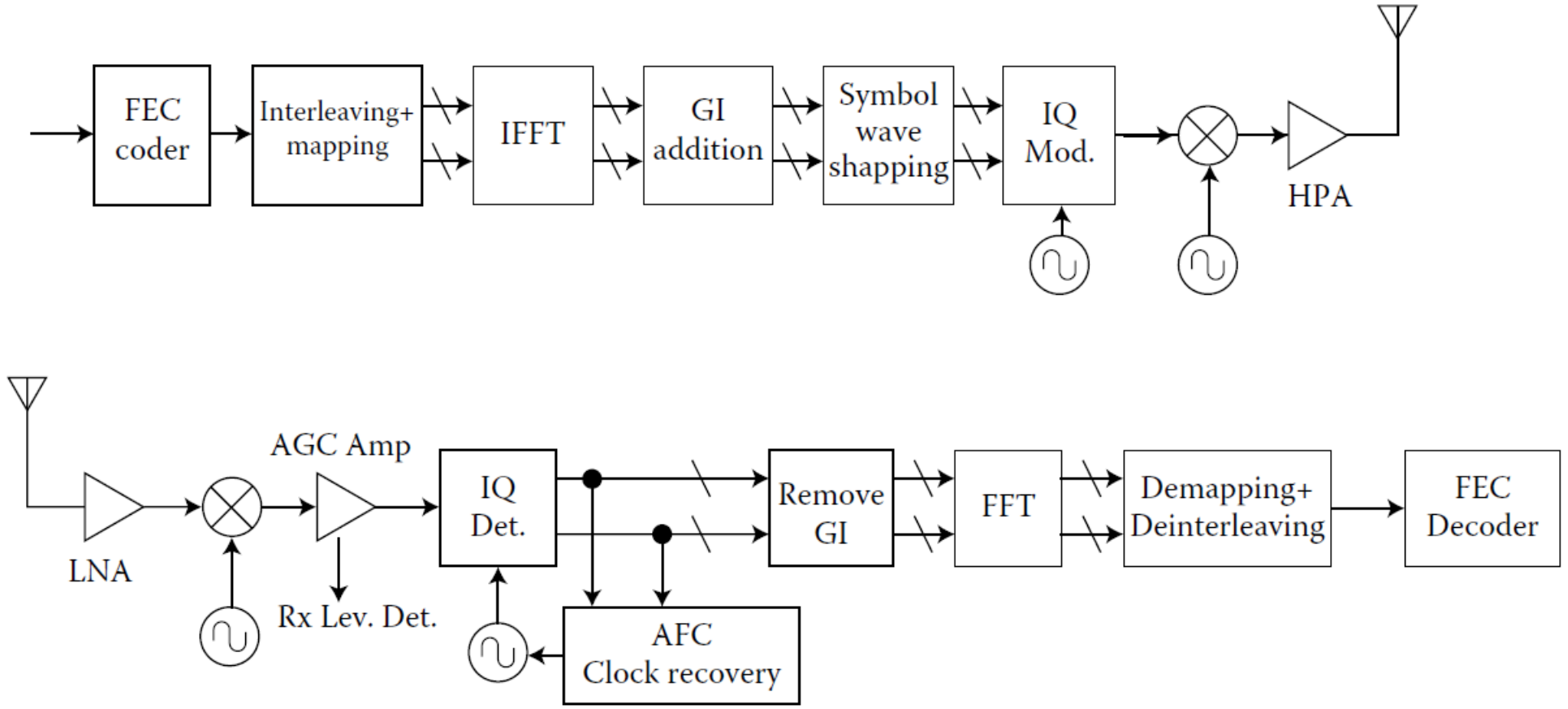
Source: Orthogonal Frequency Division Multiple Access Fundamentals and Applications (Wireless Networks and Mobile Communications) 1st Edition .

Block diagram of OFDMA uplink transmission



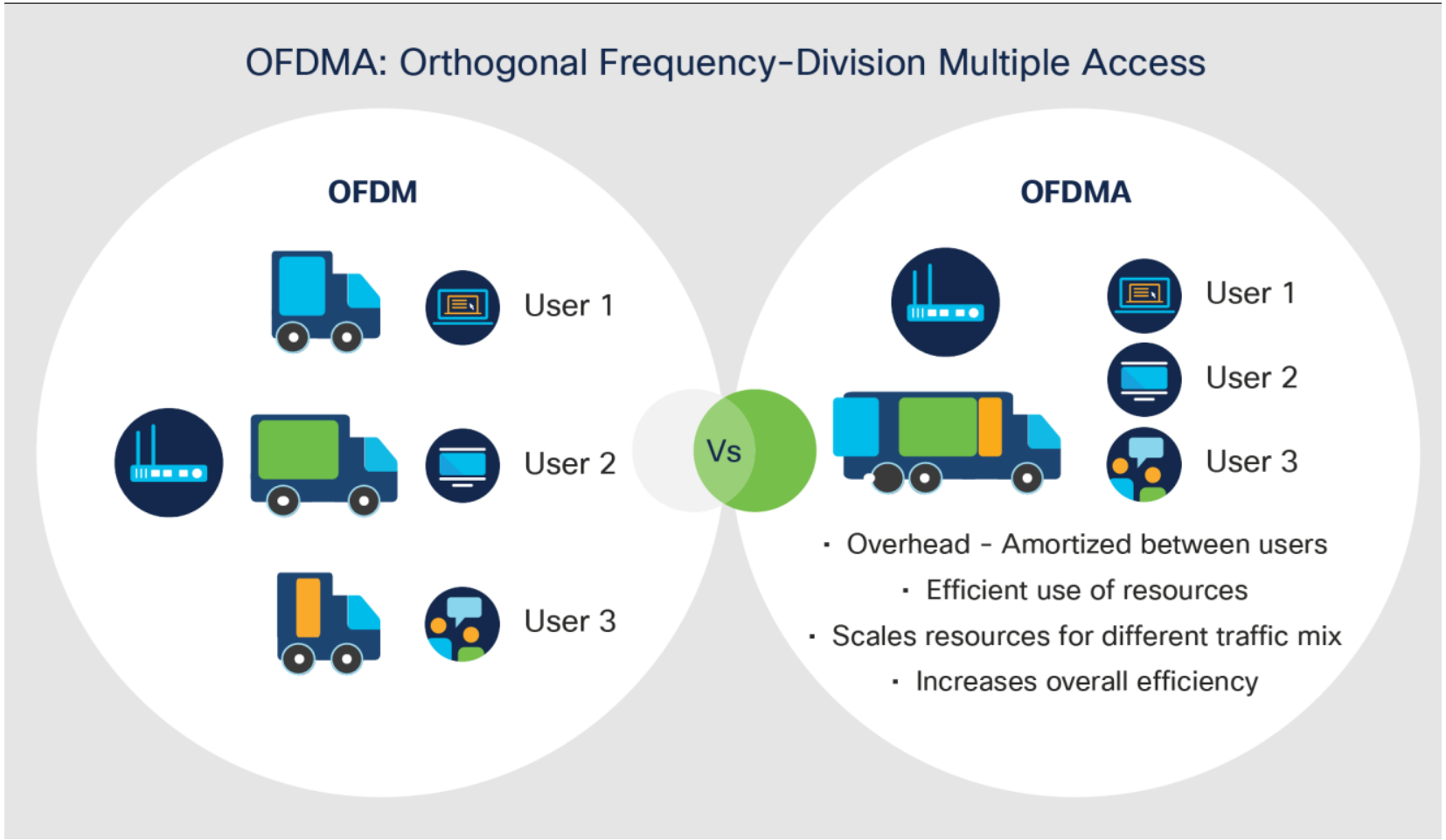
Source: Orthogonal Frequency Division Multiple Access Fundamentals and Applications (Wireless Networks and Mobile Communications) 1st Edition .

Transmitter and receiver block diagram for the OFDM PHY in IEEE 802.11a system



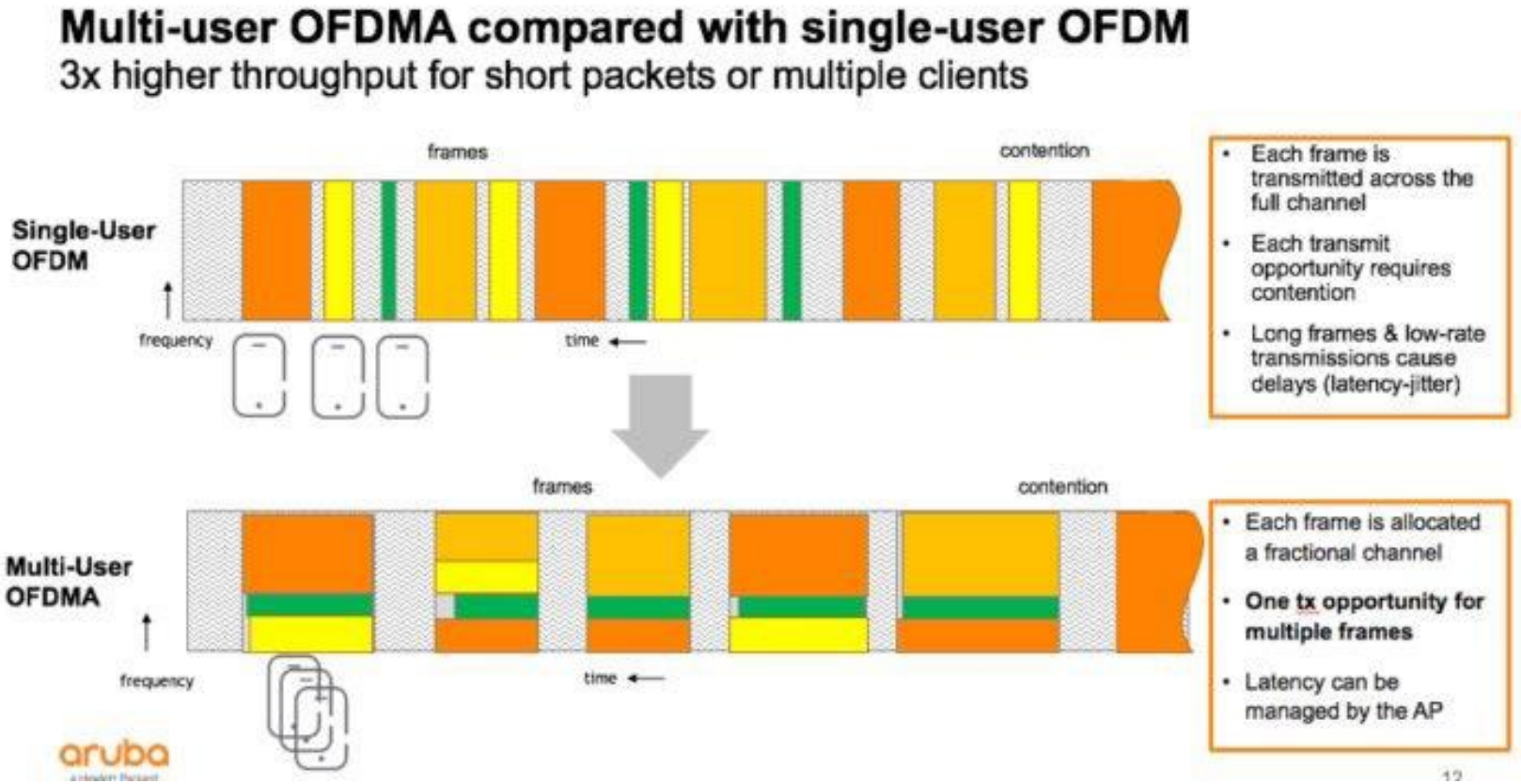
Source: Orthogonal Frequency Division Multiple Access Fundamentals and Applications (Wireless Networks and Mobile Communications) 1st Edition .

OFDM VS OFDMA

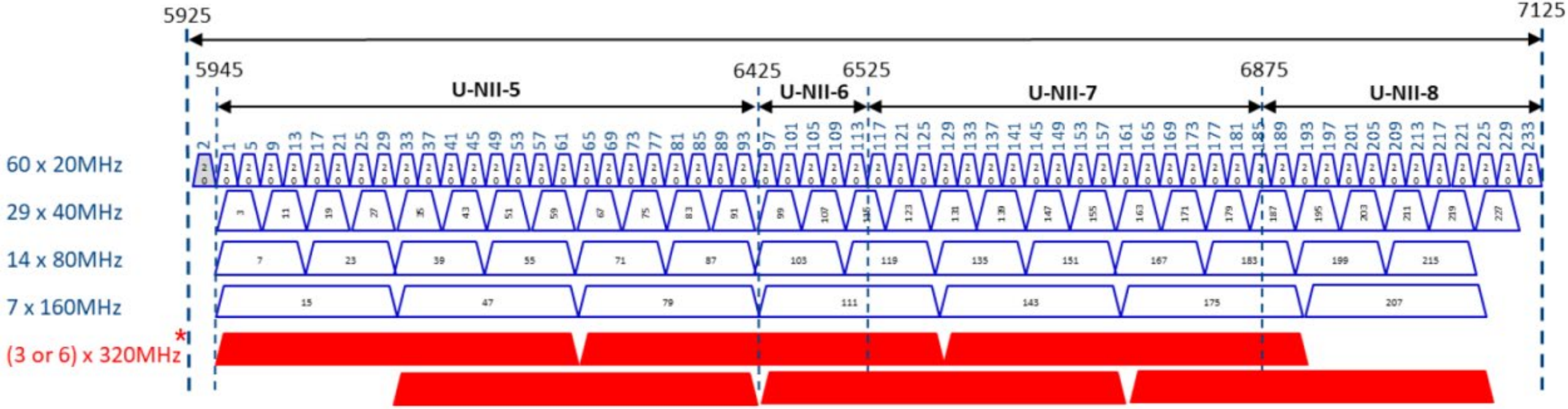


Source: CISCO. The Road to Wi-Fi 6/6E

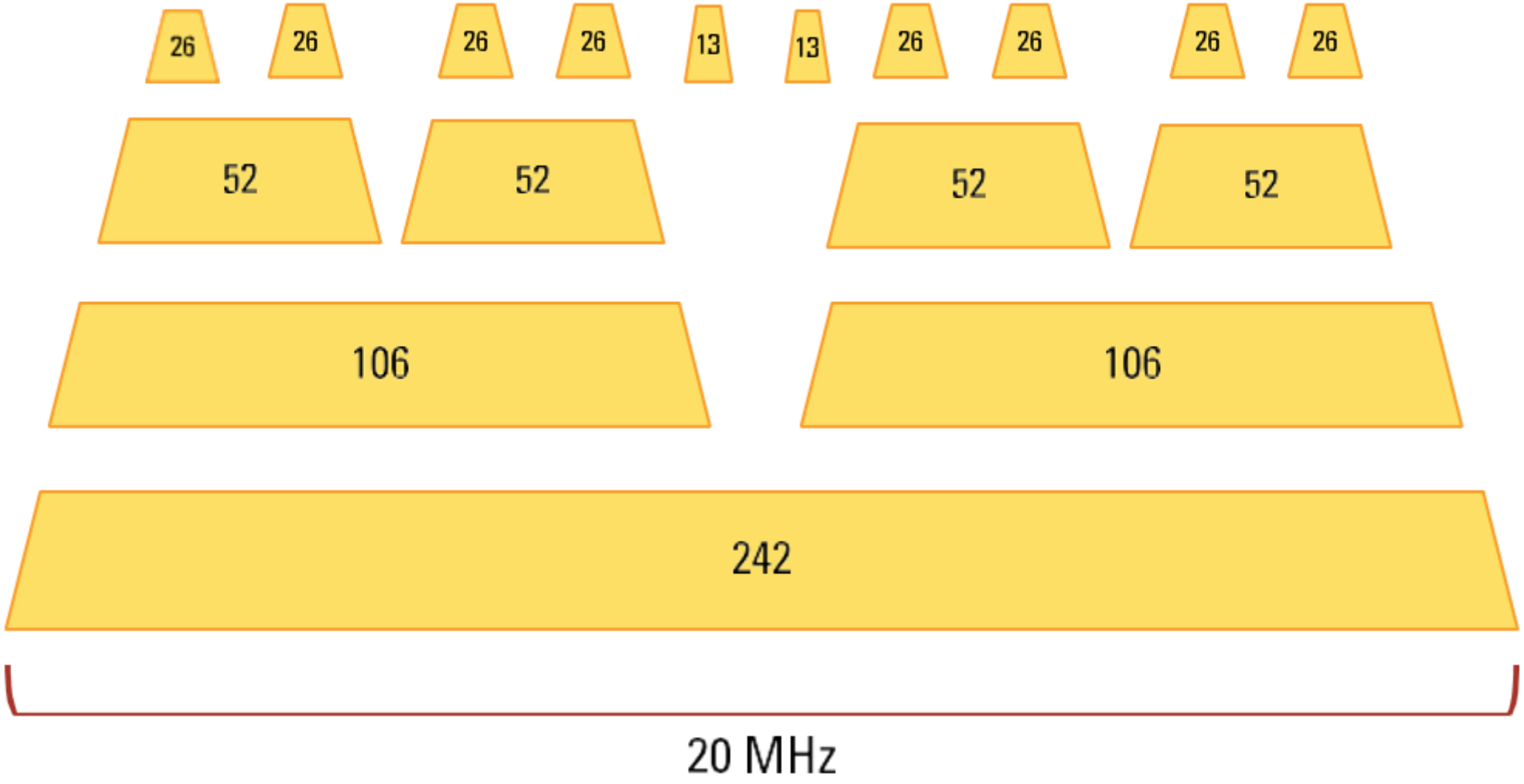
OFDM VS OFDMA



Wi-Fi 6E - 6GHz


5925
7125
5945
6425
6525
6875
U-NII-5
U-NII-6
U-NII-7
U-NII-8
60 x 20MHz
29 x 40MHz
14 x 80MHz
7 x 160MHz
(3 or 6) x 320MHz
*

GRUPOS DE RECURSO (RESOURCE GROUPS)



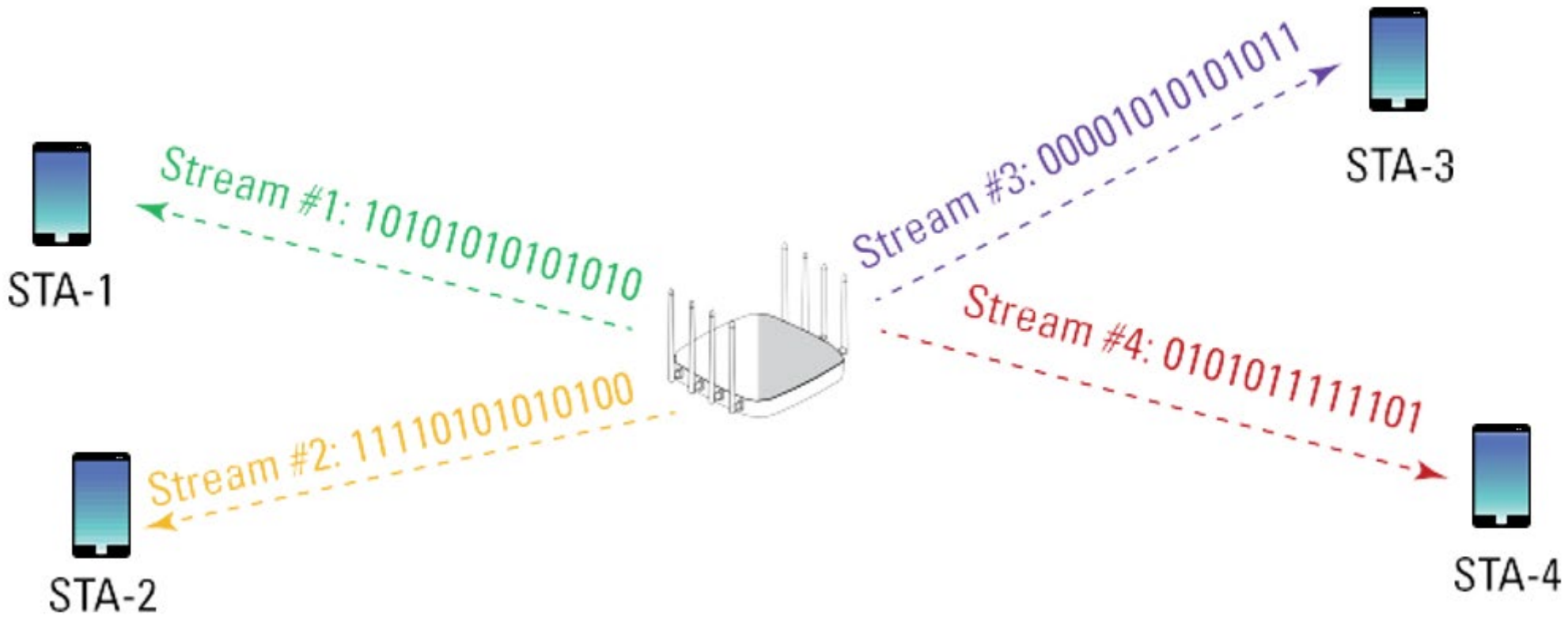
Resource Units and Wide Channels

Resource Units (RUs)	20 MHz Channel	40 MHz Channel	80 MHz Channel	160 MHz Channel	80 + 80 MHz Channel
996 (2x) subcarriers	n/a	n/a	n/a	1 client	1 client
996 subcarriers	n/a	n/a	1 client	2 clients	2 clients
484 subcarriers	n/a	1 client	2 clients	4 clients	4 clients
242 subcarriers	1 client	2 clients	4 clients	8 clients	8 clients
106 subcarriers	2 clients	4 clients	8 clients	16 clients	16 clients
52 subcarriers	4 clients	8 clients	16 clients	32 clients	32 clients
26 subcarriers	**9 clients**	**18 clients**	**37 clients**	**74 clients**	**74 clients**

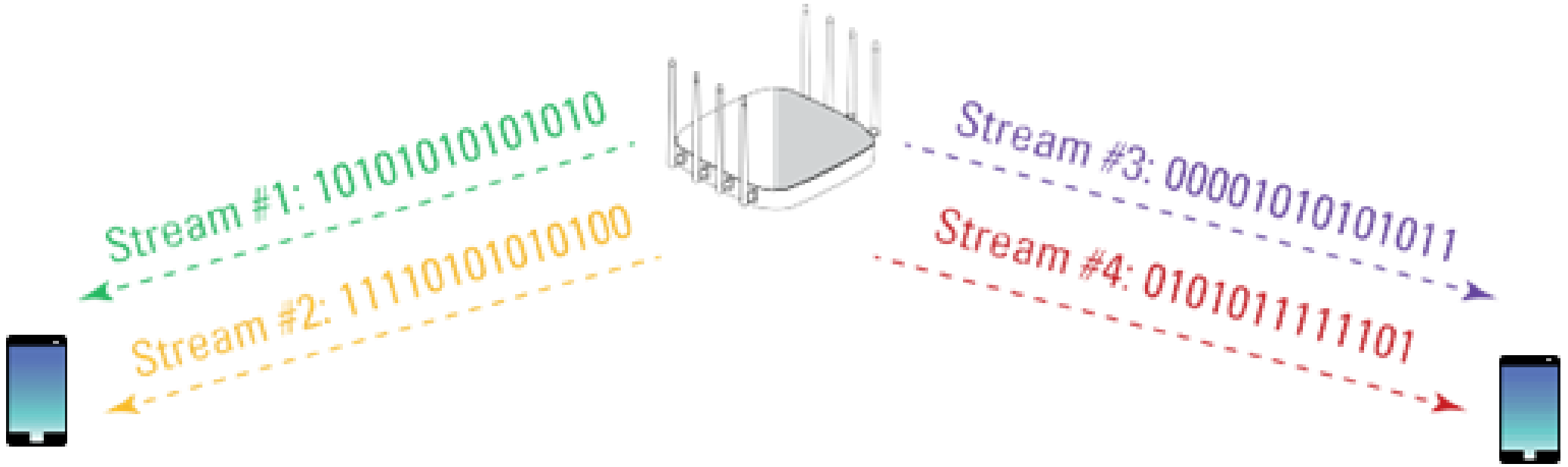
TRÊS TIPOS DE SUBPORTADORAS

- **Data subcarriers**: These subcarriers will use the same modulation and coding schemes (MCSs) as 802.11ac as well as two new MCSs with the addition of 1024 quadrature amplitude modulation (1024-QAM).
- **Pilot subcarriers**: The pilot subcarriers do not carry any modulated data; however, they are used for synchronization purposes between the transmitter and receiver.
- **Unused subcarriers**: The remaining unused subcarriers are mainly used as guard carriers or null subcarriers against interference from adjacent channels or subchannels.

MU-MIMO


Stream #1: 10101010101010
Stream #2: 11110101010100
Stream #3: 00001010101011
Stream #4: 01010111111101
STA-1
STA-2
STA-3
STA-4

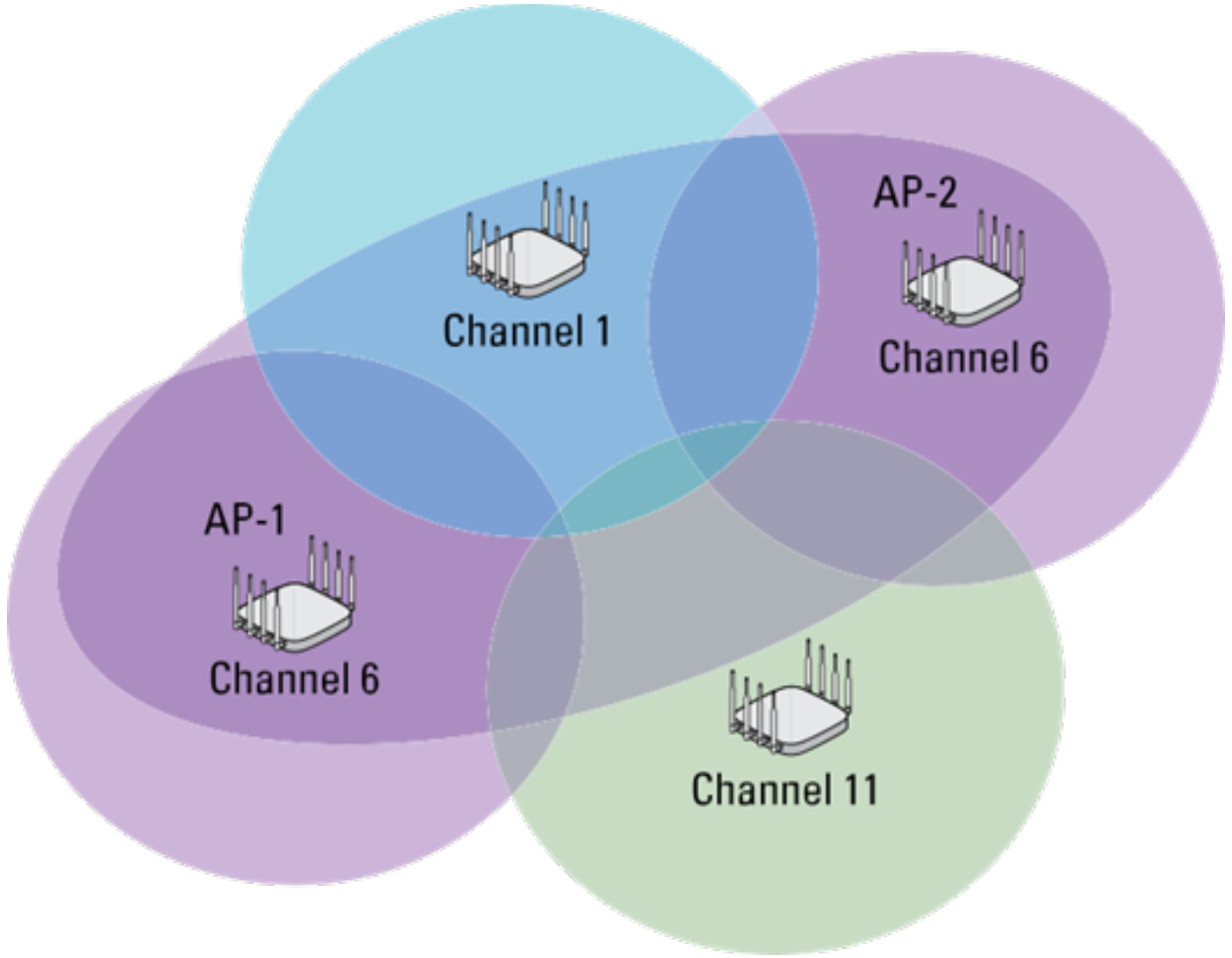
Downlink MU-MIMO – 4×4:4:4:2.



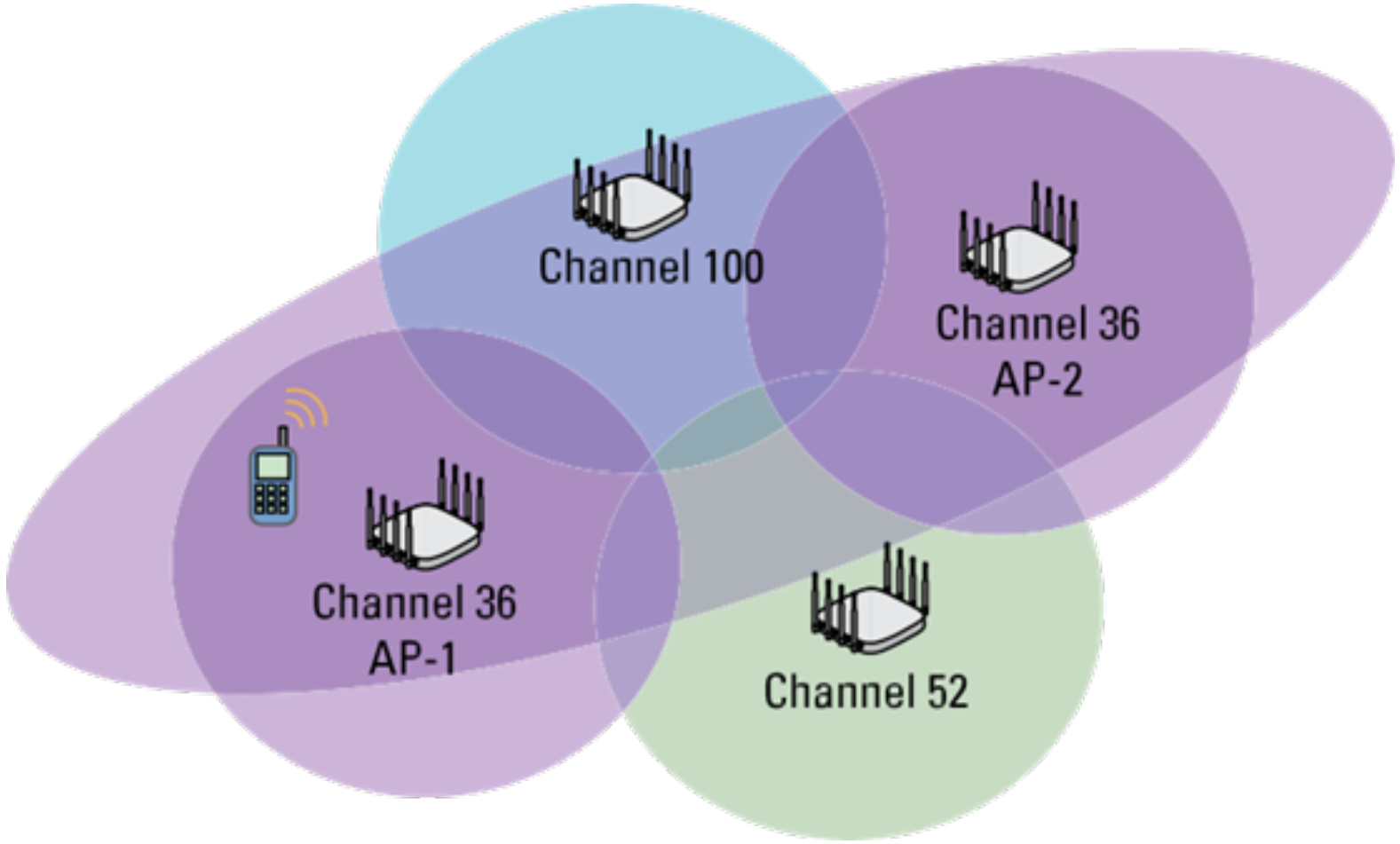
OFDMA VS MU-MIMO

OFDMA	MU-MIMO
Increased efficiency	Increased capacity
Reduced latency	Higher data rates per user
Best for low-bandwidth applications	Best for high-bandwidth applications
Best with small packets	Best with large packets

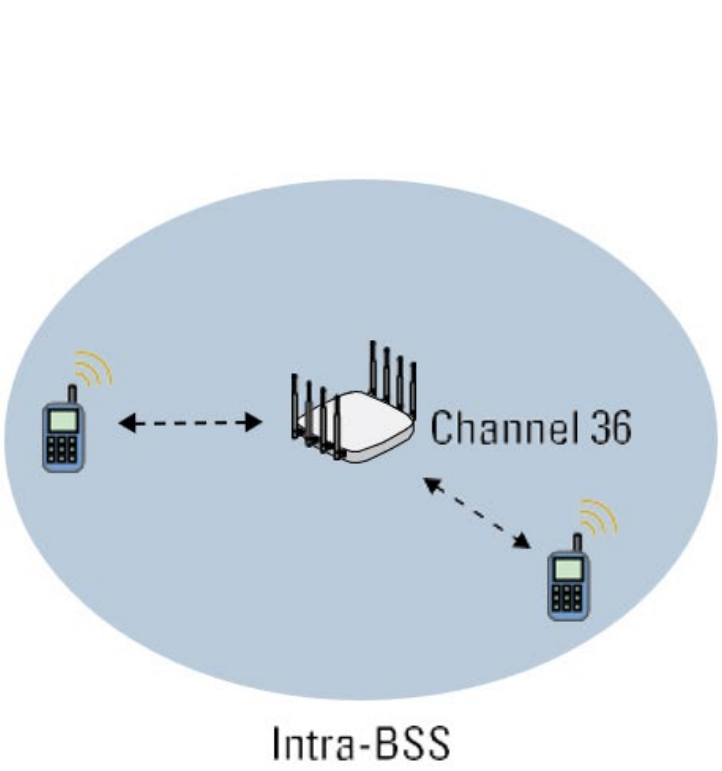
OBSS – Overlapping basic service set

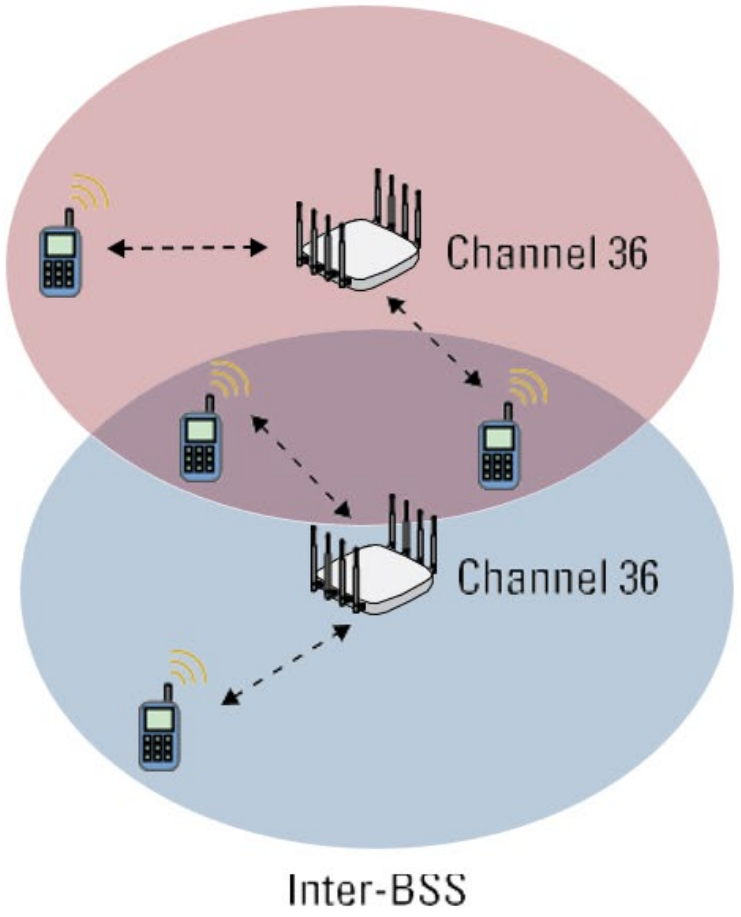


OBSS interference caused by client

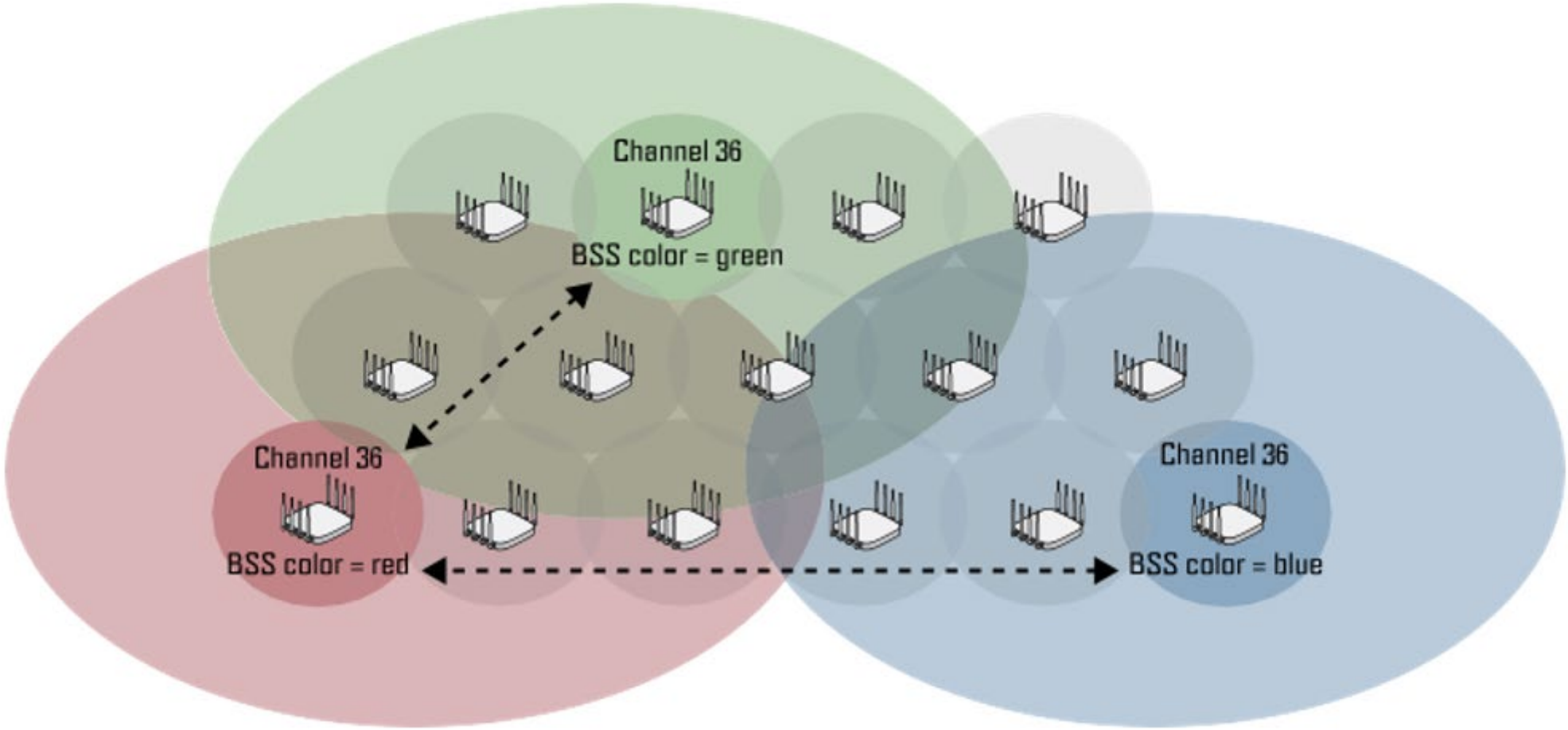


BSS COLOR

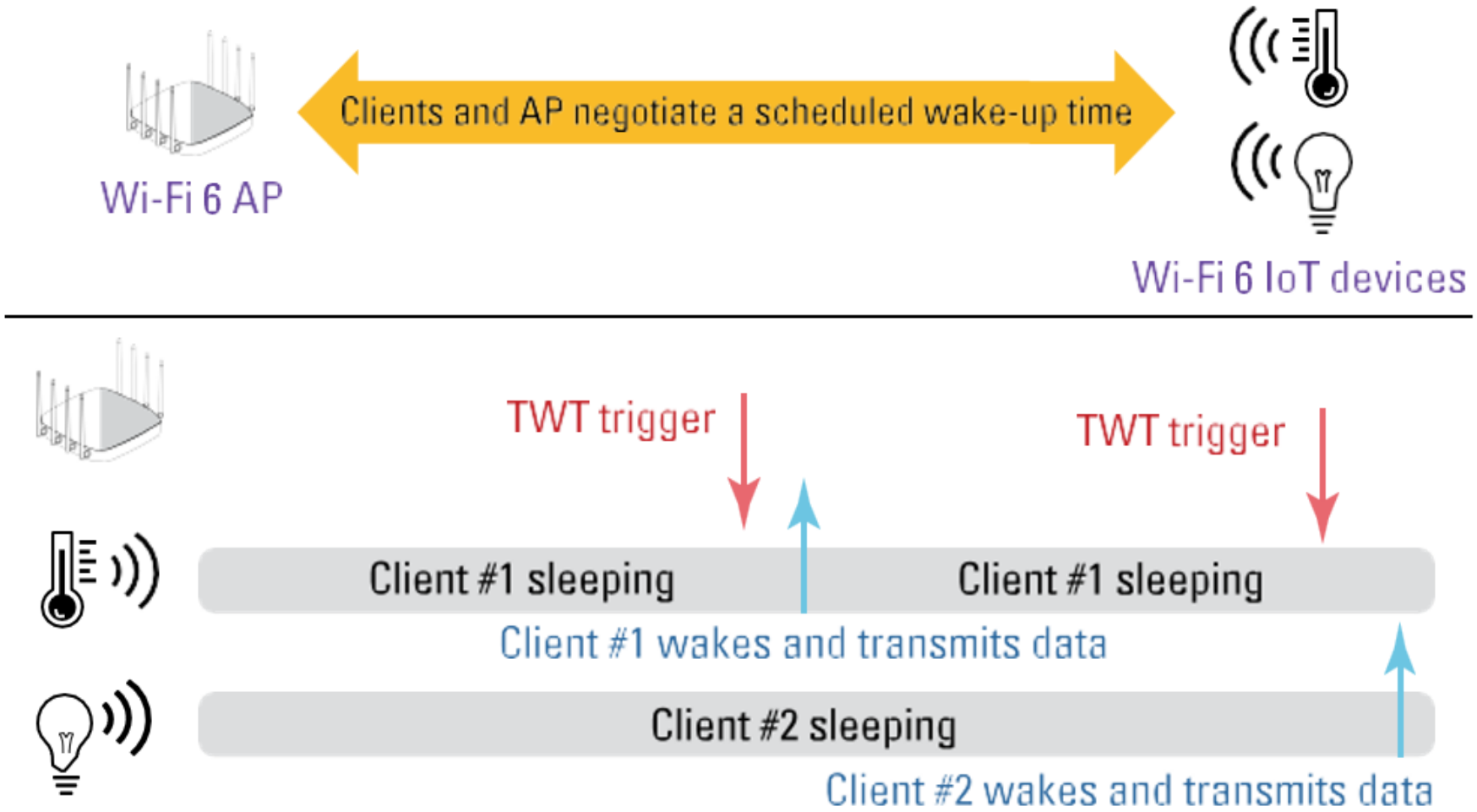




INTER-BSS

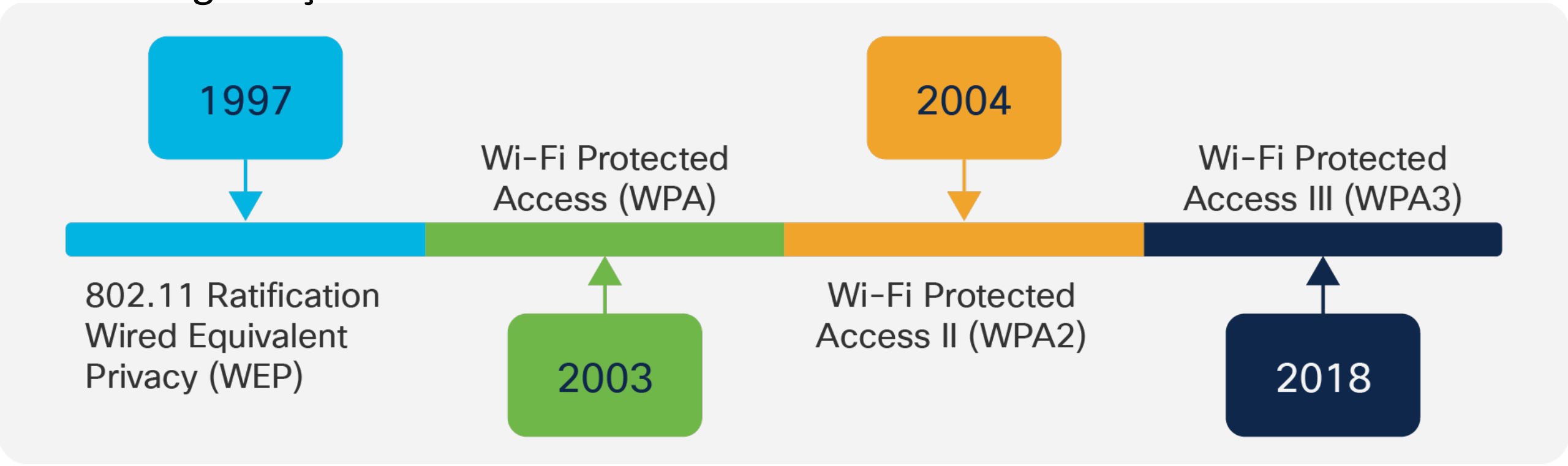

Channel 36
BSS color = green
Channel 36
BSS color = red
Channel 36
BSS color = blue

TARGET WAKE TIME



OUTROS

- Segurança



DÚVIDAS?

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