

Introduction to WiFi Networks

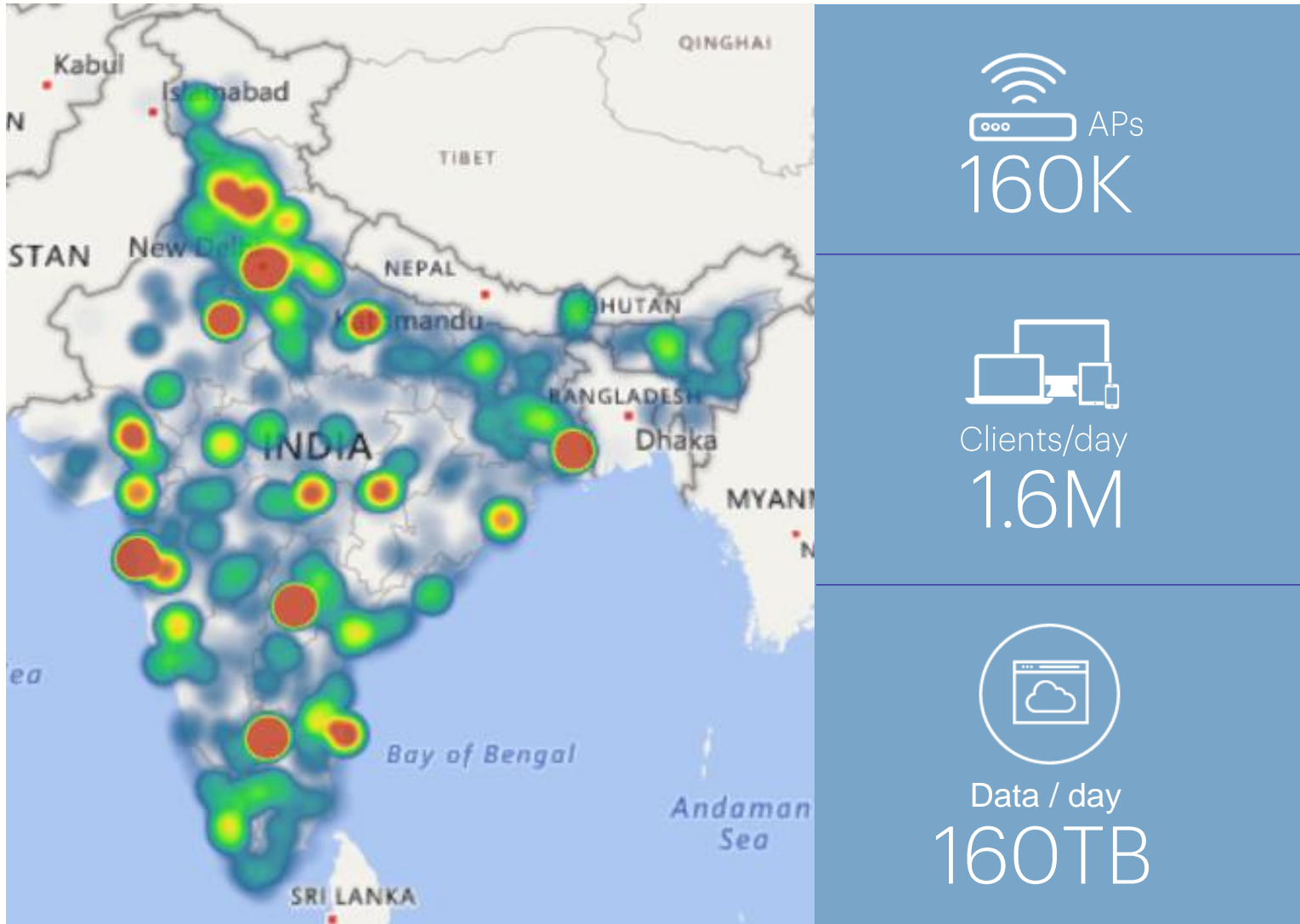
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WiFi Consulting Services Team, Arista Networks






























Massively scalable Wi-Fi Networks



Jio WiFi: Powered by Arista Mojo Networks



Global Presence Across Multiple Verticals

Large Enterprise	Distributed Enterprise	Education	Service Providers &	Federal	BFSI
      	      	       	      	         	         



Wireless Technologies

Wireless Technologies



Wireless Technology Classification

Access type

- Fixed
- Nomadic
- Portable
- Mobile

Technology type

- Standard
- Proprietary

Coverage

- Local
- Metro
- Wide Area

Spectrum

- Licensed
- Unlicensed

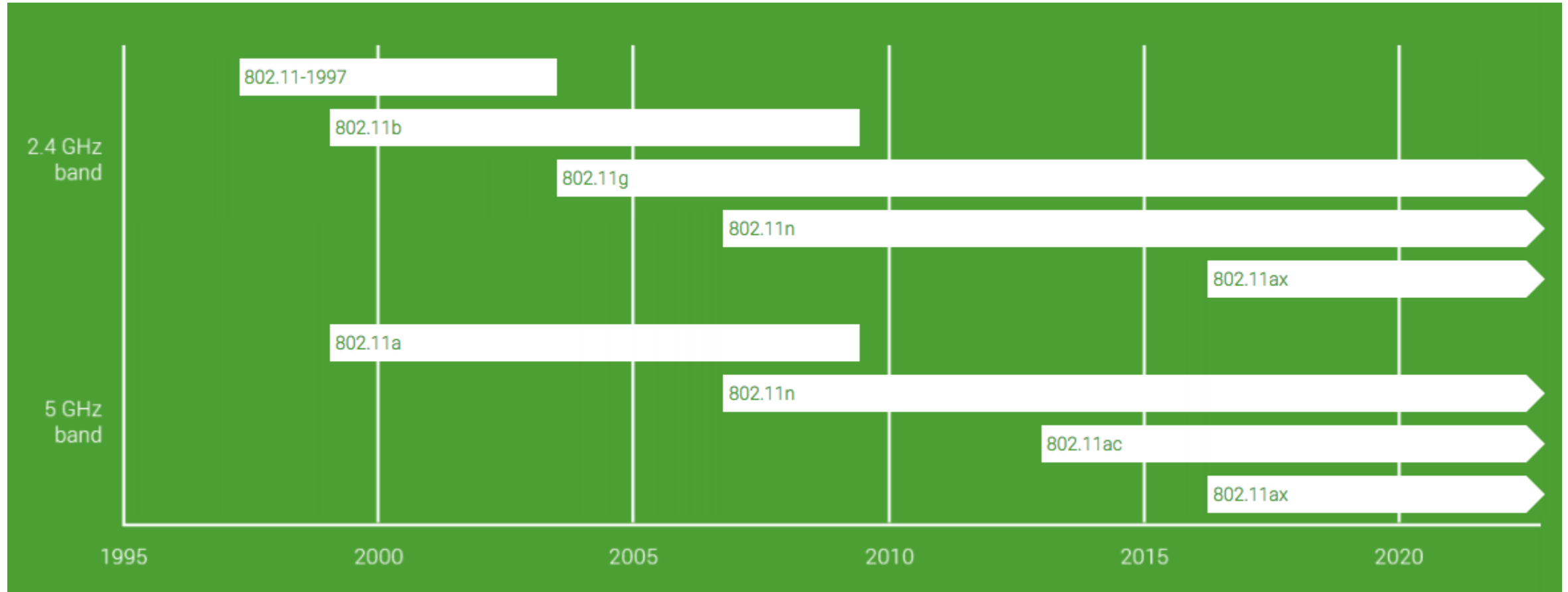
WiFi Technology Overview

Use Cases



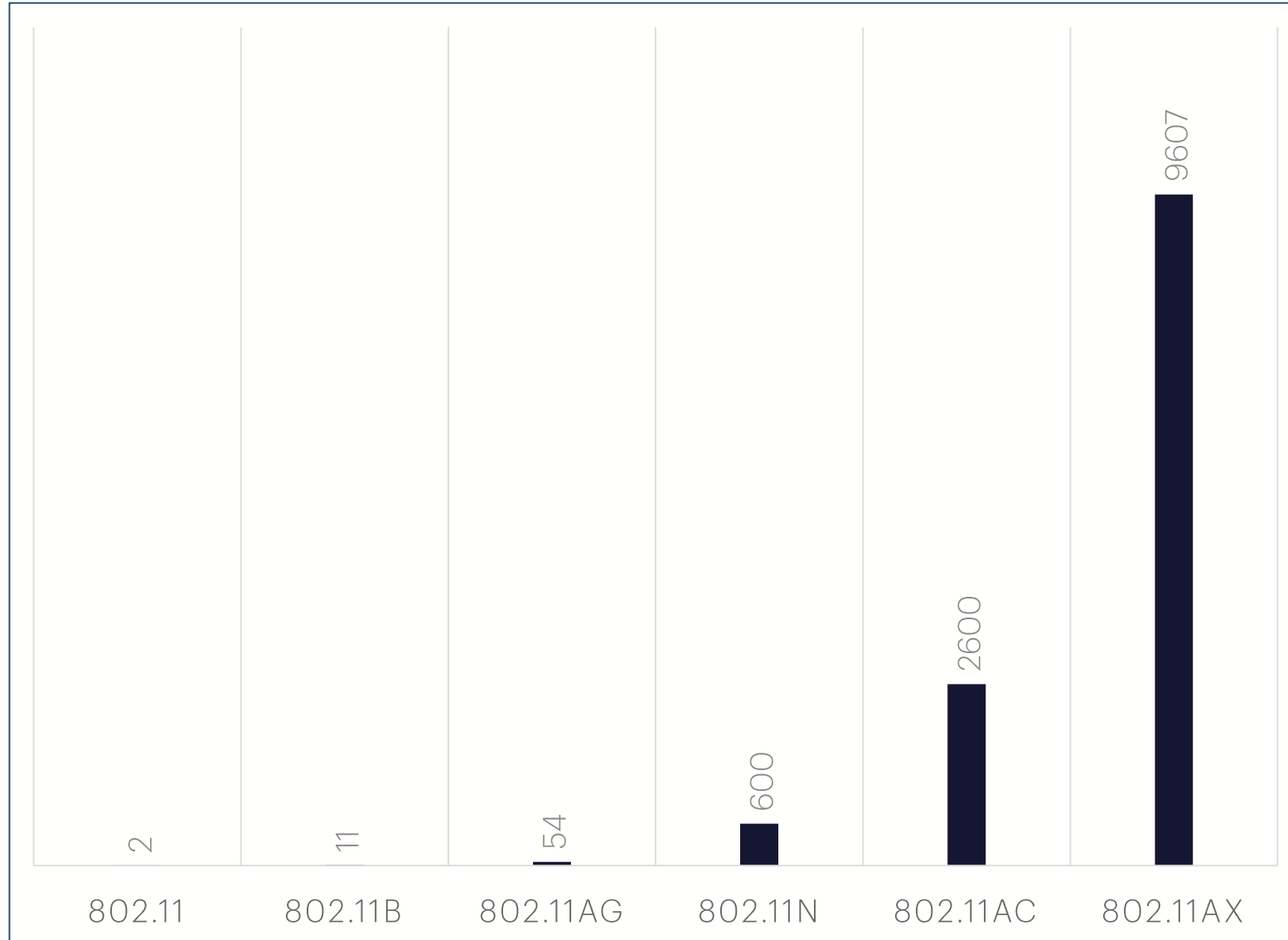
Source: Broadcom

WiFi Standards



Source: National Instruments

The Rat(e) Race



WiFi Connection Speeds

Region	2017	2018	2019	2020	2021	2022	CAGR (2017–2022)
Global	24.4	30.3	36.3	42.2	48.2	54.2	17%
Asia Pacific	26.7	34.5	42.2	47.6	56.0	63.3	19%
Latin America	9.0	10.6	12.1	13.8	15.2	16.8	13%
North America	37.1	46.9	56.8	63.6	74.4	83.8	18%
Western Europe	25.0	30.8	36.3	37.7	44.6	49.5	15%
Central and Eastern Europe	19.5	22.6	24.1	27.4	30.1	32.8	11%
Middle East and Africa	6.2	7.0	7.9	9.6	10.2	11.2	13%

Source: Cisco VNI, 2018.

WiFi Everywhere

Part of the solutions to
“1000x mobile data
challenge”



Wi-Fi supported in
all smart devices

At the center of
connected home



The universal technology
for smart connected homes

Opening new frontiers for
wireless connectivity



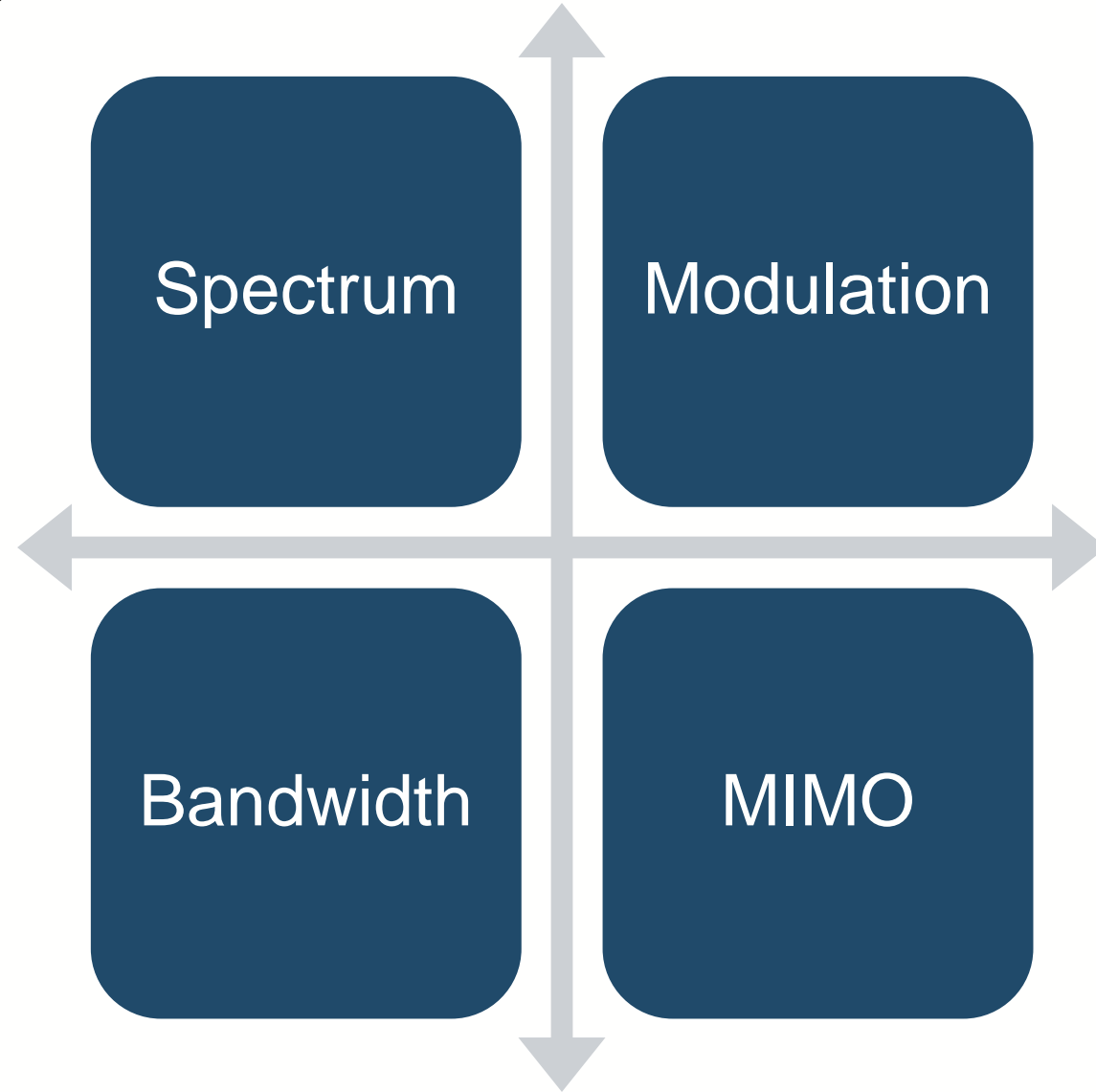
Leveraging ubiquity of indoor Wi-Fi for
many new applications and services

Source: Qualcomm



WiFi Technology Building Blocks

Basic Building Blocks of WiFi



Spectrum

Licensed

- Exclusive allocation to an entity such as a telecom/Internet service provider
- E.g. 2.1 GHz band

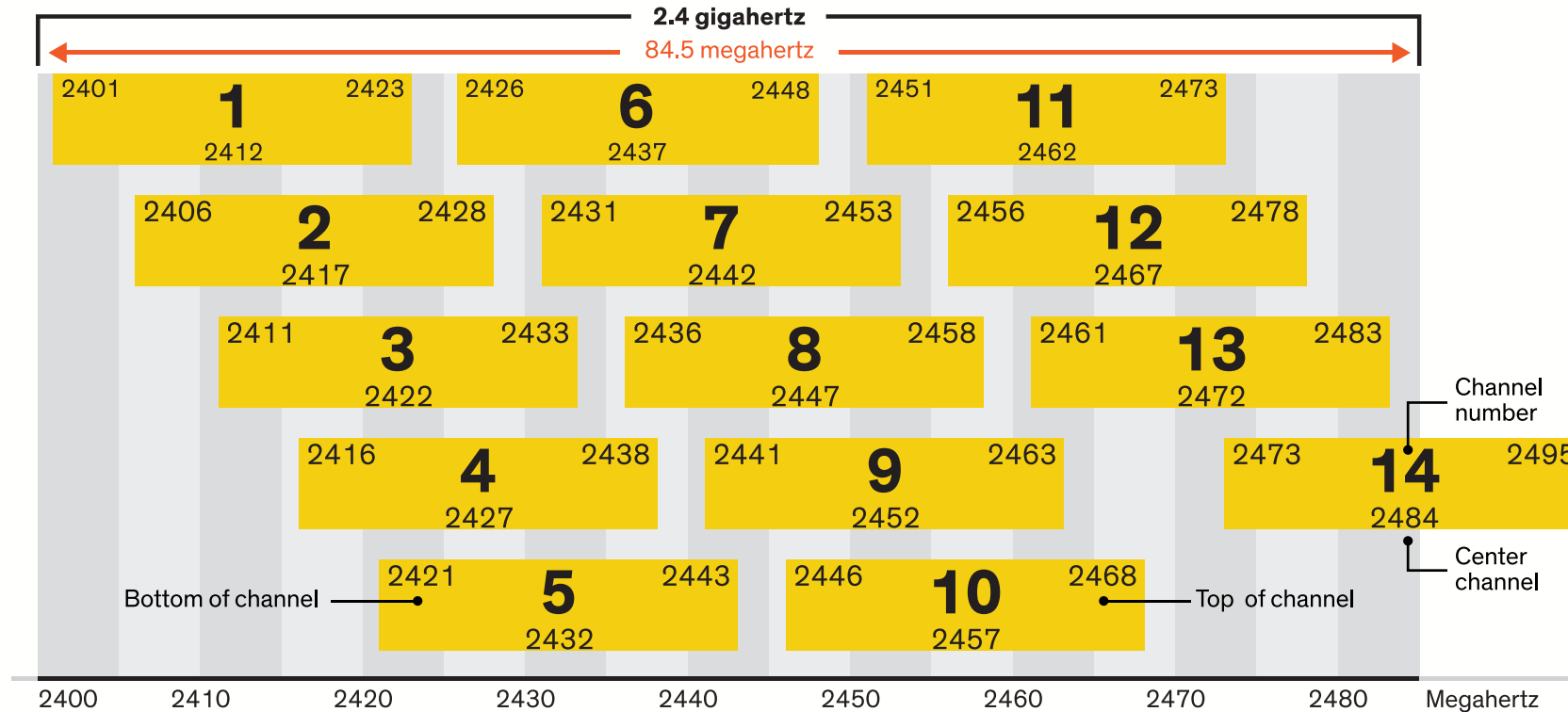
Unlicensed

- Non-exclusive right to use
- Available for both personal and commercial use
- E.g. 2.4 GHz band

Lightly Licensed

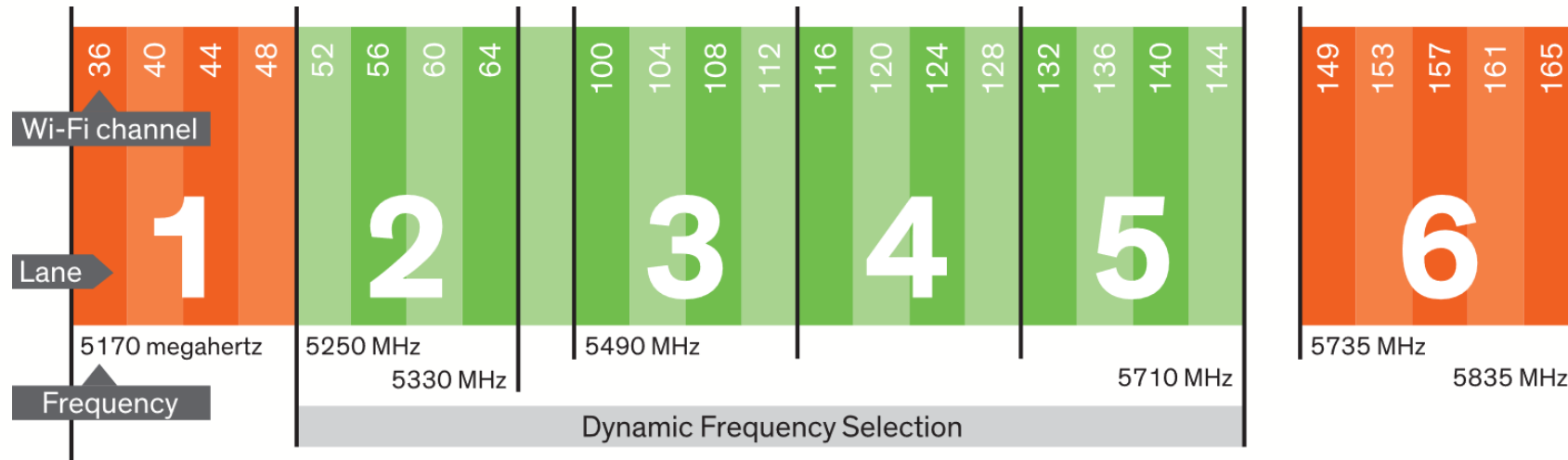
- Shared use of spectrum by licensed users
- Right to use based on time/location
- E.g. 3.5 GHz band

WiFi Spectrum (1/2)



Source: IEEE Spectrum

WiFi Spectrum (2/2)

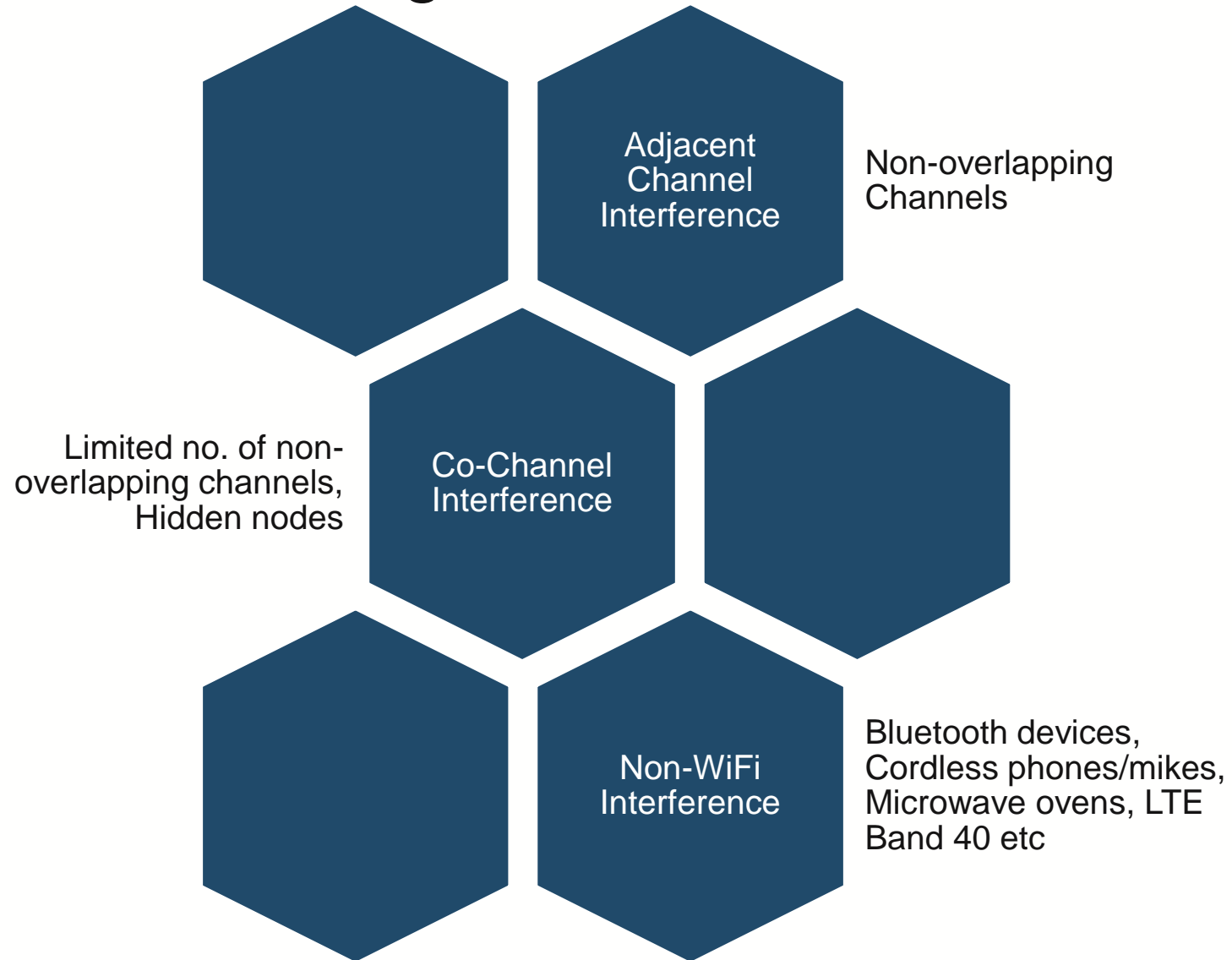


Source: IEEE Spectrum

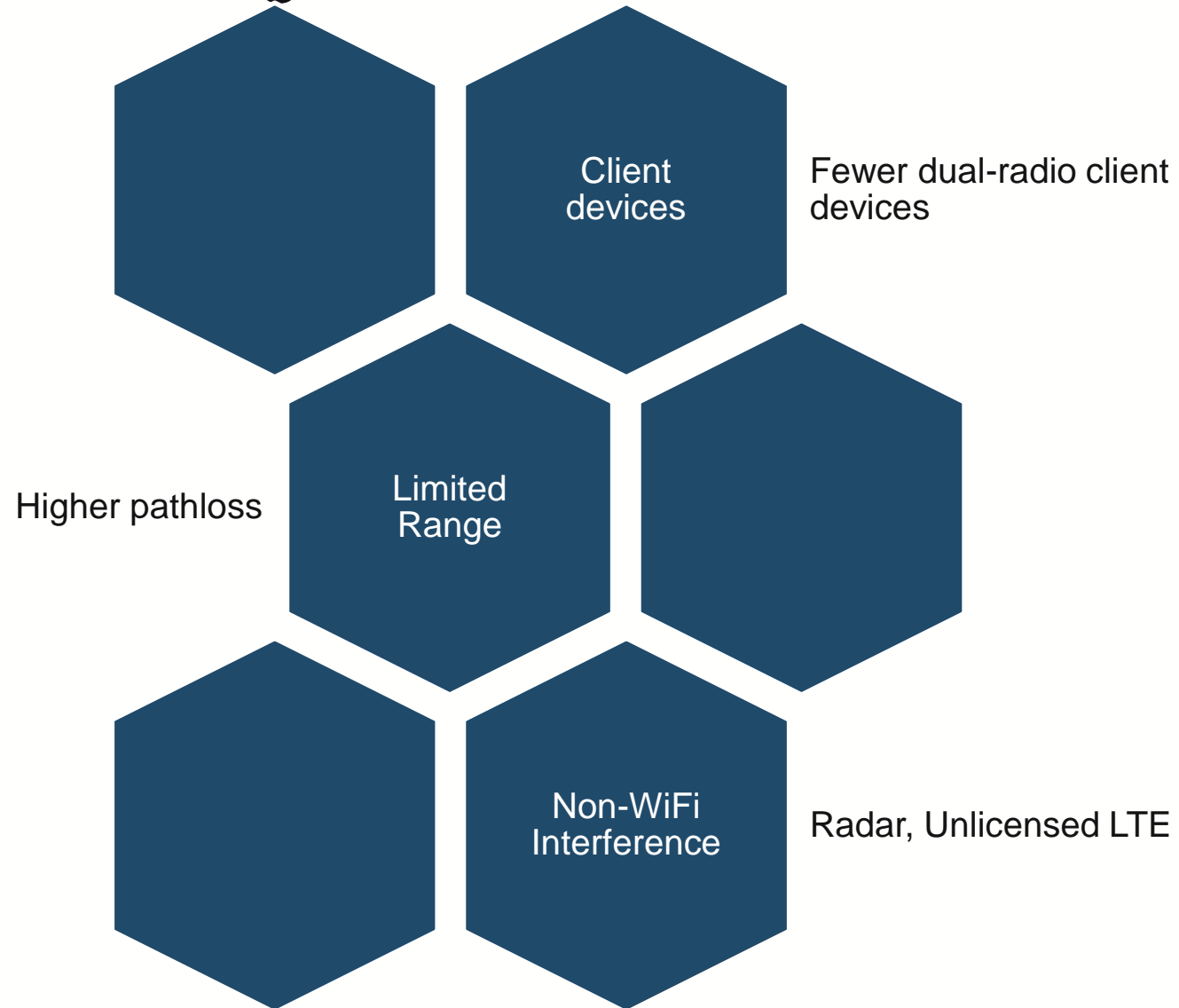
Band Support

	2.4G	5G
802.11b	Y	N
802.11a	N	Y
802.11g	Y	N
802.11n	Y	Y
802.11ac	N	Y
802.11ax	Y	Y

2.4 GHz Band Challenges



5 GHz Band Challenges



Dynamic Frequency Selection (DFS)

Channel Availability Check

- Before selecting a DFS channel, the AP checks for radar signal on the channel for 60 seconds.
- If no signal is detected, AP can start using the channel

In-service Monitoring

- While operating on a DFS channel, AP continues to check for radar signals.
- If radar is detected, AP stops transmission on the channel and moves to another channel
- AP cannot use this channel for at least 30 minutes after radar detection

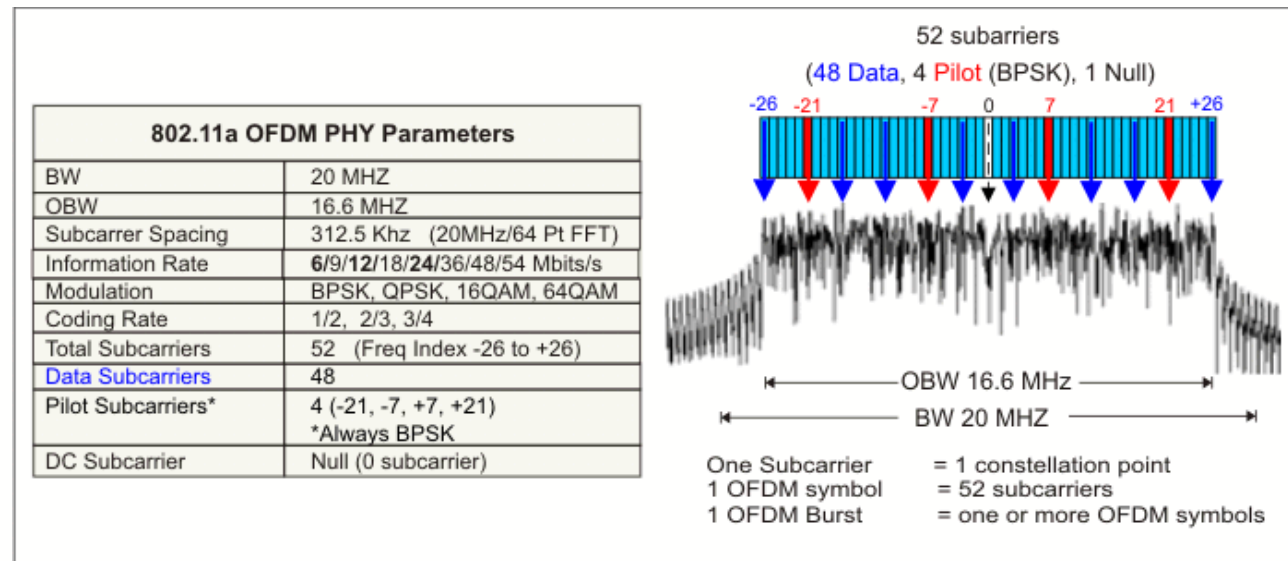
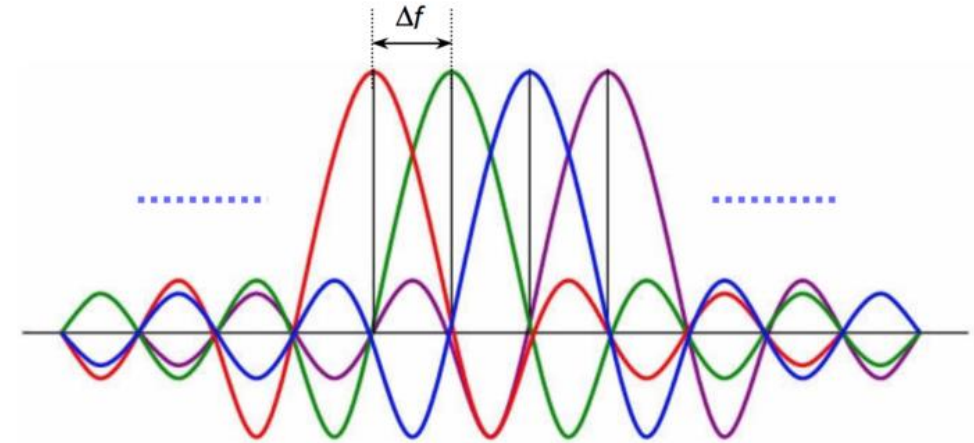
Channel Switch Announcement

- AP may inform clients about the new channel to which it is shifting

Suggested reading: **The 5GHz “Problem” For Wi-Fi Networks: DFS**
<http://wifinigel.blogspot.com/2018/05/the-5ghz-problem-for-wi-fi-networks-dfs.html>

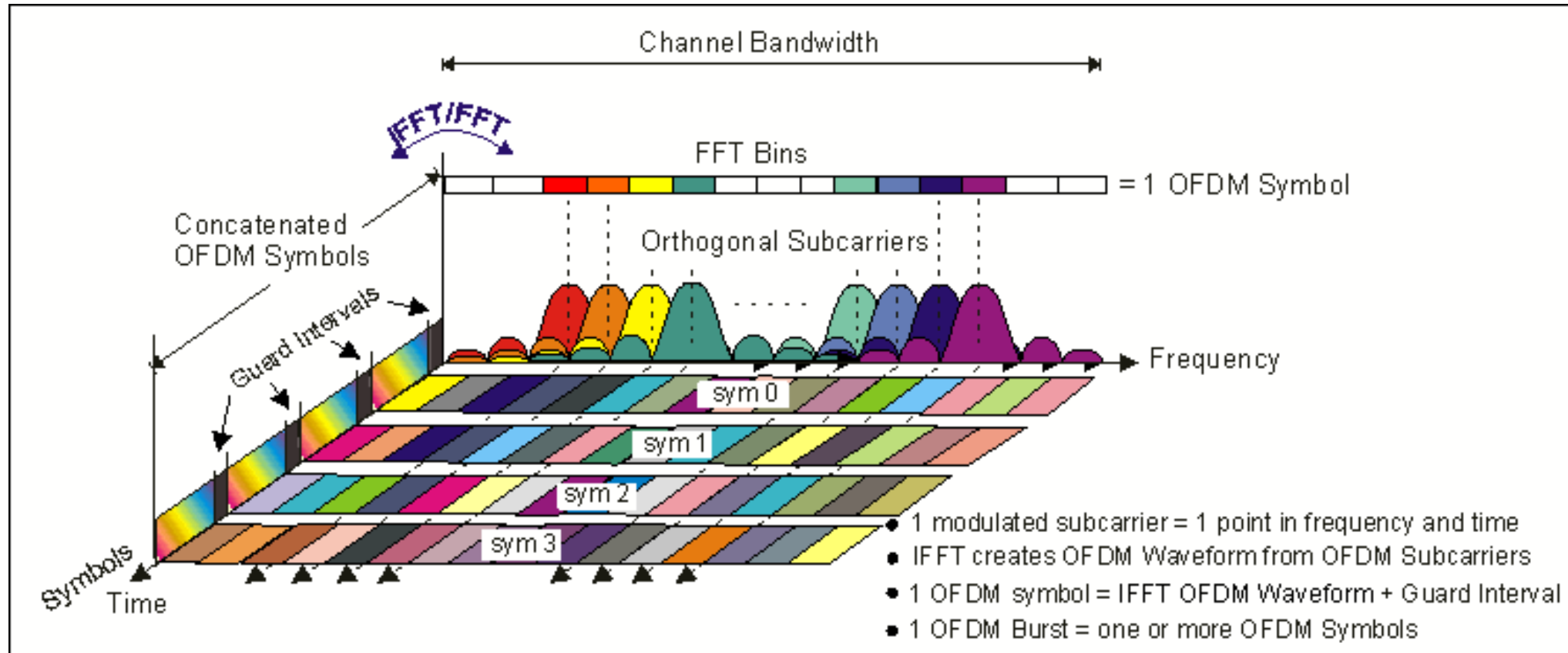
Modulation

- Orthogonal Frequency Division Multiplexing (OFDM)
 - Available bandwidth is divided into subcarriers
 - Subcarriers are orthogonal to each other
 - Subcarrier spacing equals the reciprocal of symbol duration



802.11a OFDM Physical Parameters

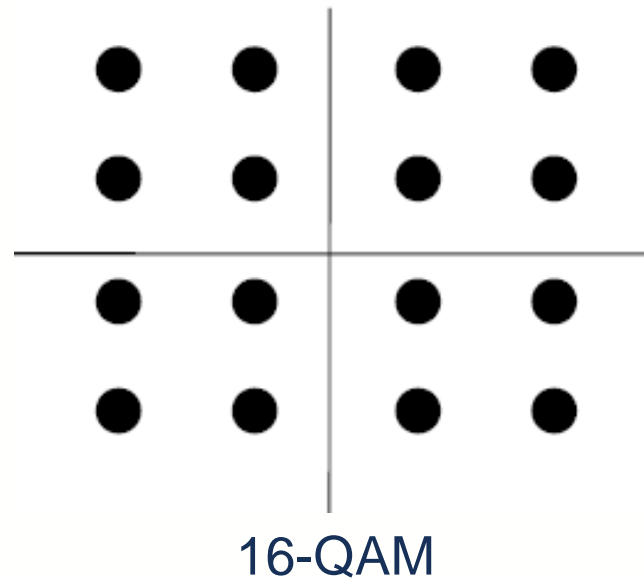
OFDM Waveform



Frequency-Time Representative of an OFDM signal

Modulation

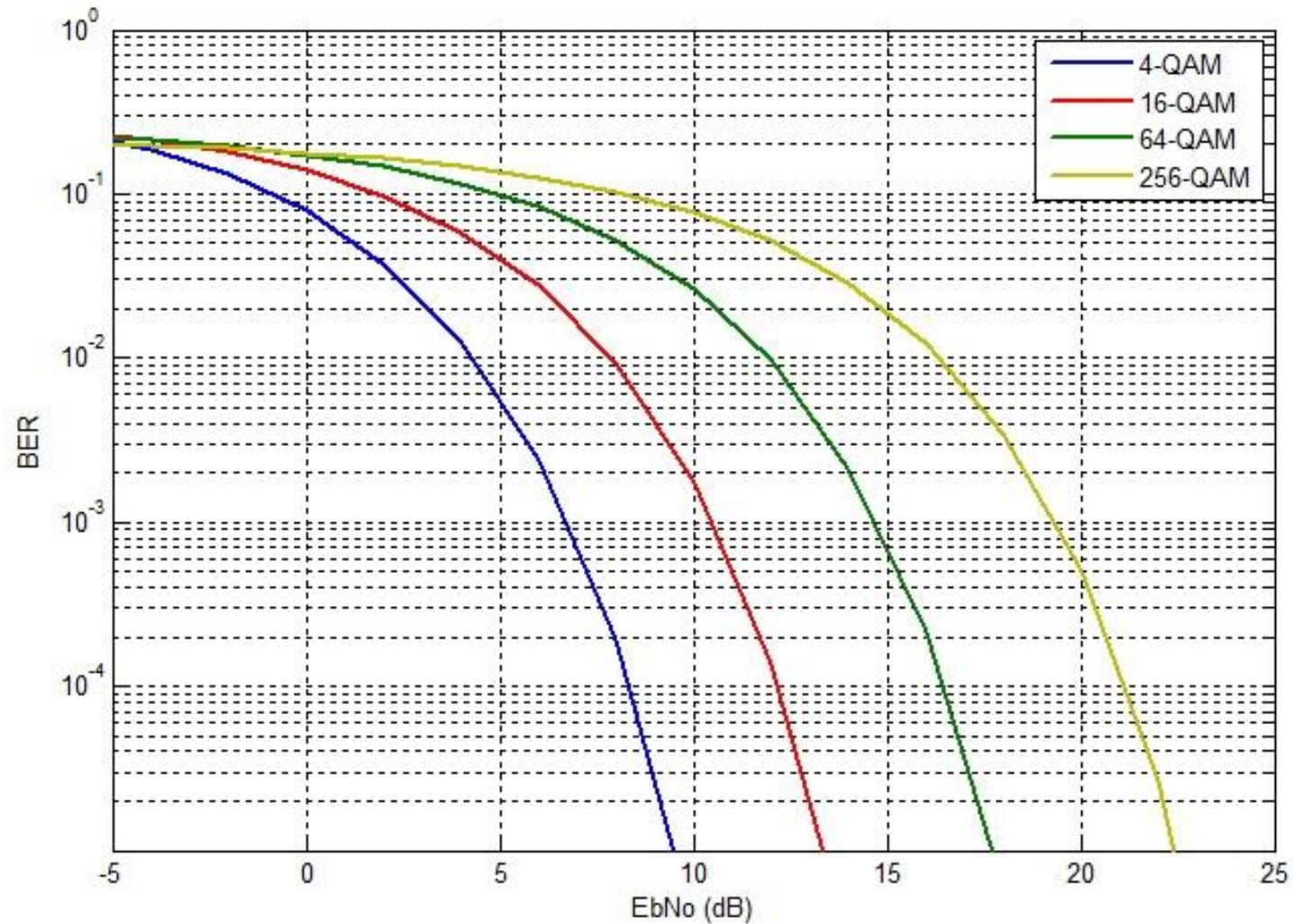
- Quadrature Amplitude Modulation (QAM) is used to modulate the OFDM subcarriers
 - QAM makes use of both amplitude and phase are used to send information



MCS to Data Rate Mapping

Data Rate Mbits/s	Modulation	Coding Rate R	Coded bits per subcarrier	Coded bits per OFDM symbol	Data bits per OFDM symbol
6	BPSK	1/2	1	48	24
9	BPSK	3/4	1	48	36
12	QPSK	1/2	2	96	48
18	QPSK	3/4	2	96	72
24	16-QAM	1/2	4	192	96
36	16-QAM	3/4	4	192	144
48	64-QAM	2/3	6	288	192
54	64-QAM	3/4	6	288	216

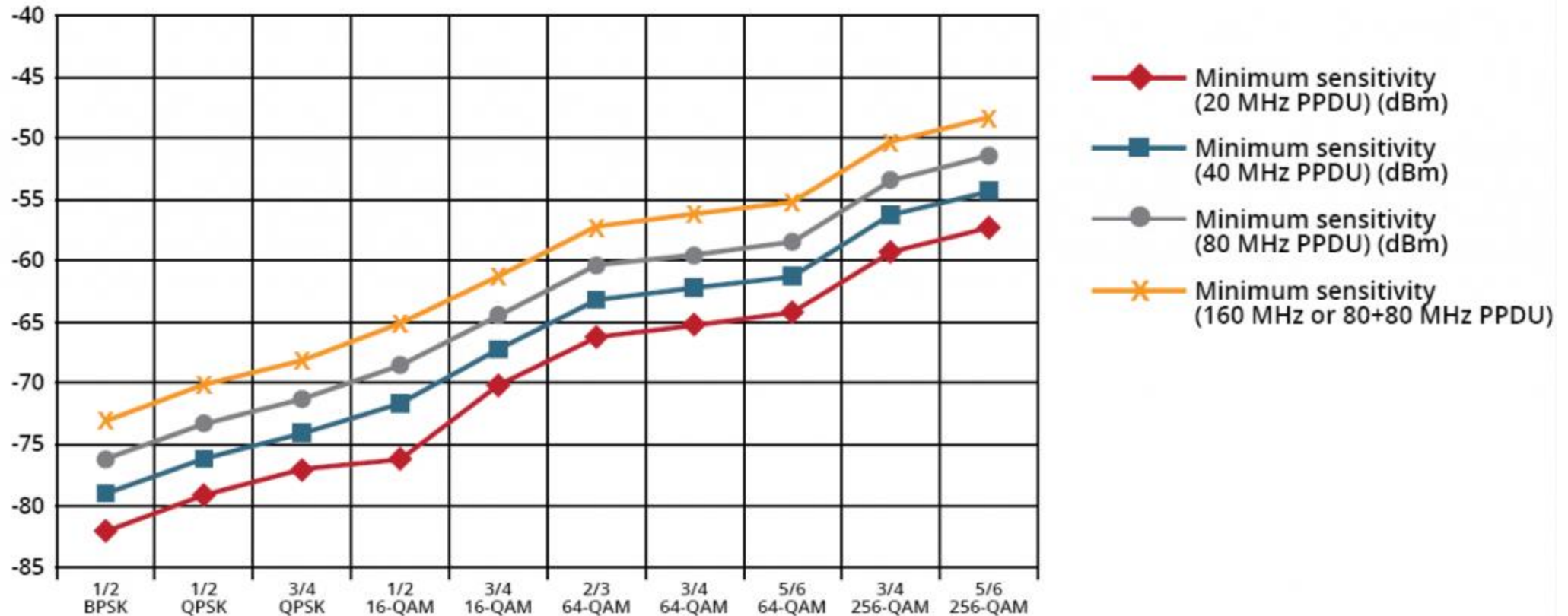
Adaptive Modulation



Source: http://www.raymaps.com/index.php/qam-theoretical-ber/qam_theoretical_ber/

Receiver Sensitivity

- Receiver sensitivity is the minimum signal power at which a receiver test is able to receive data with a defined maximum packet error rate (PER) of 10%.



Source: 7Signals

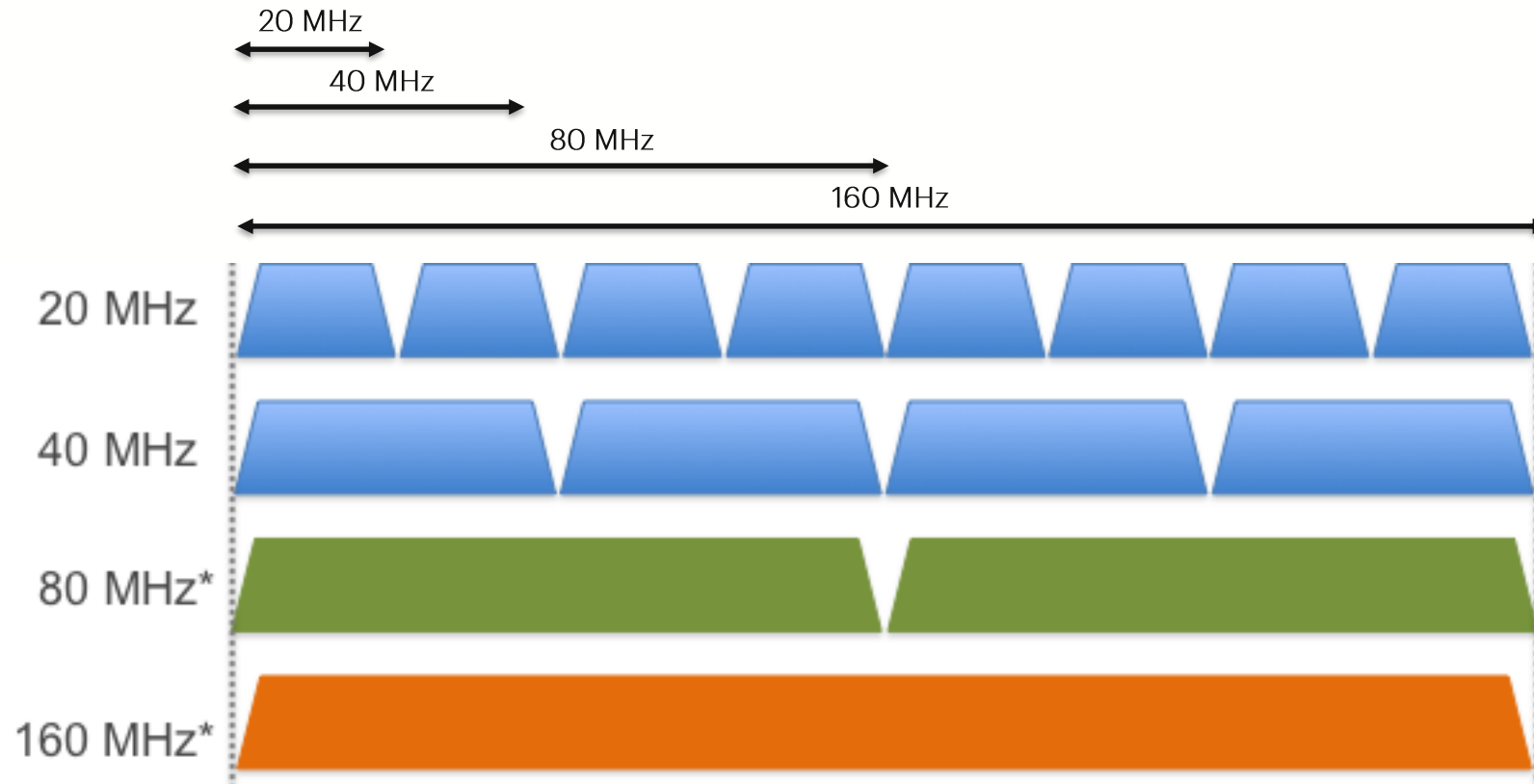
SNR to MCS Mapping

MCS Value Achieved by Clients at Various Signal to Noise Ratio Levels (SNR)

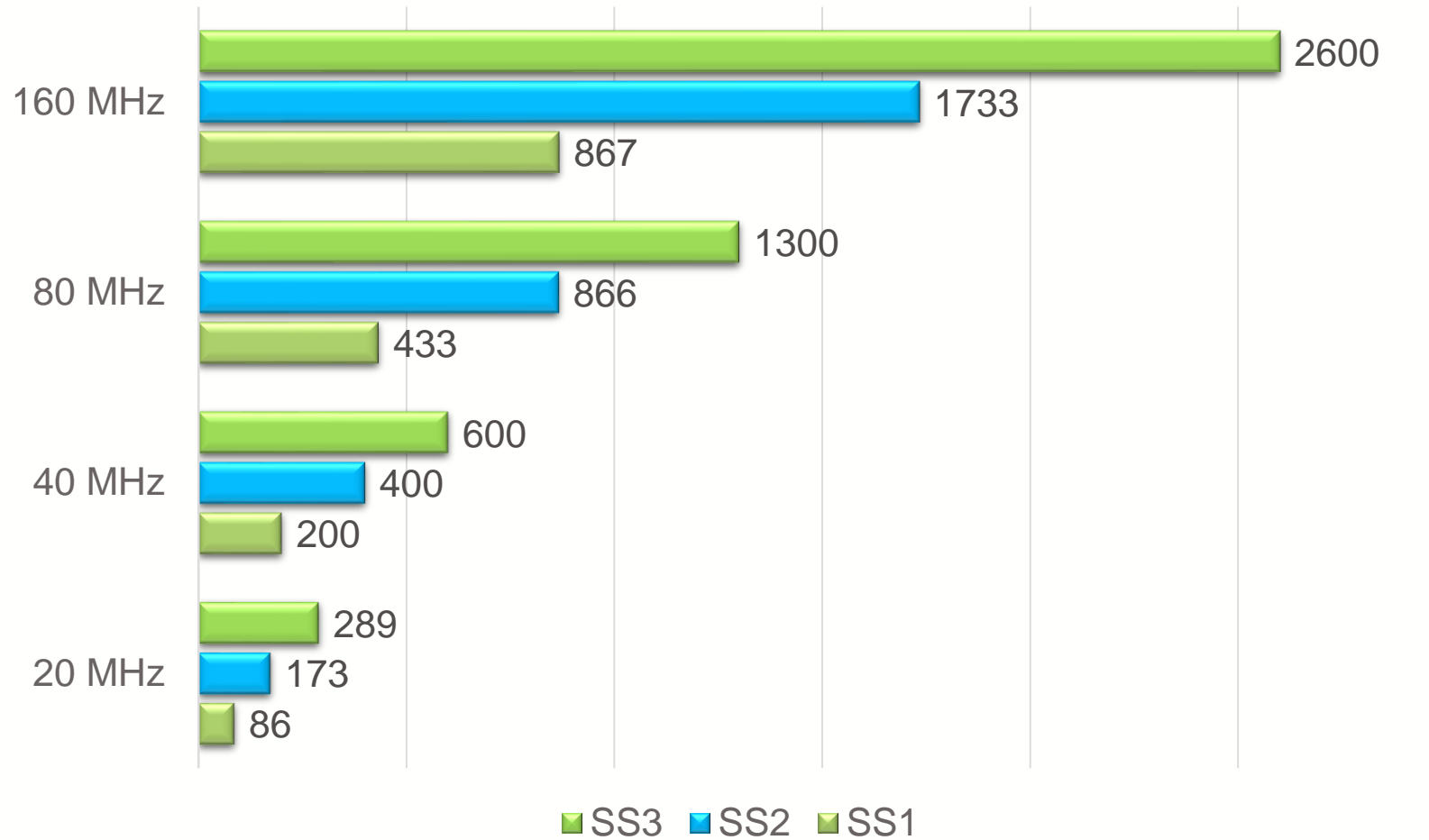
Protocol	Channel	1	2	3	4	5	6	7	8	9	10	Modulation Key
802.11b	20MHz	None	None	None	MCS 0	MCS 0	MCS 0	MCS 1	MCS 1	MCS 1	MCS 1	
802.11a/g	20MHz	None	MCS 0	MCS 0	MCS 1	MCS 2	MCS 2	MCS 2	MCS 2	MCS 3	MCS 3	None = Grey
802.11n	20MHz	None	MCS 0	MCS 0	MCS 0	MCS 1	MCS 1	MCS 1	MCS 1	MCS 2	MCS 2	BPSK = Red
802.11n	40MHz	None	None	None	None	MCS 0	MCS 0	MCS 0	MCS 1	MCS 1	MCS 1	QPSK = Orange
802.11ac	20MHz	None	MCS 0	MCS 0	MCS 0	MCS 1	MCS 1	MCS 1	MCS 1	MCS 2	MCS 2	16-QAM = Yellow
802.11ac	40MHz	None	None	None	None	MCS 0	MCS 0	MCS 0	MCS 1	MCS 1	MCS 1	64-QAM = Blue
802.11ac	80MHz	None	None	None	None	None	None	None	MCS 0	MCS 0	MCS 0	256-QAM = Green
802.11ac	160MHz	None	None	None	None	None	None	None	None	None	None	
SNR in dB		11	12	13	14	15	16	17	18	19	20	802.11 Type Key
802.11b	20MHz	MCS 2	MCS 2	MCS 2	MCS 2	MCS 2	MCS 3	MCS 3	MCS 3	MCS 3	MCS 3	
802.11a/g	20MHz	MCS 4	MCS 4	MCS 4	MCS 4	MCS 5	MCS 5	MCS 5	MCS 6	MCS 6	MCS 7	802.11b
802.11n	20MHz	MCS 3	MCS 3	MCS 3	MCS 3	MCS 4	MCS 4	MCS 4	MCS 5	MCS 5	MCS 6	802.11ag
802.11n	40MHz	MCS 1	MCS 2	MCS 2	MCS 3	MCS 3	MCS 3	MCS 3	MCS 4	MCS 4	MCS 4	802.11n
802.11ac	20MHz	MCS 3	MCS 3	MCS 3	MCS 3	MCS 4	MCS 4	MCS 4	MCS 5	MCS 5	MCS 6	802.11ac
802.11ac	40MHz	MCS 1	MCS 2	MCS 2	MCS 3	MCS 3	MCS 3	MCS 3	MCS 4	MCS 4	MCS 4	
802.11ac	80MHz	MCS 1	MCS 1	MCS 1	MCS 1	MCS 2	MCS 2	MCS 3	MCS 3	MCS 3	MCS 3	
802.11ac	160MHz	MCS 0	MCS 0	MCS 0	MCS 1	MCS 1	MCS 1	MCS 1	MCS 2	MCS 2	MCS 3	

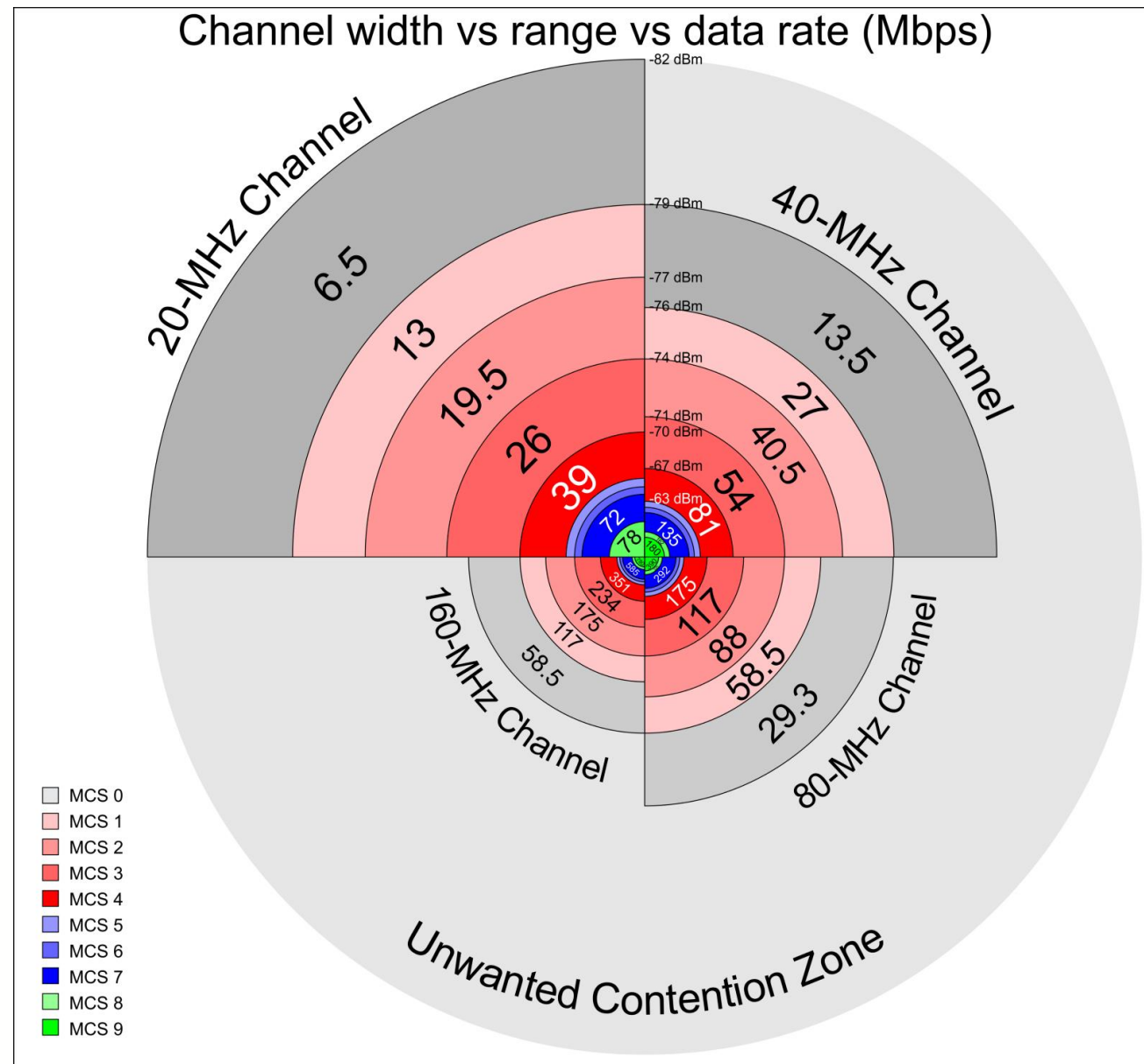
Source: Revolution WiFi

Channel Bandwidth



Bandwidth Aggregation



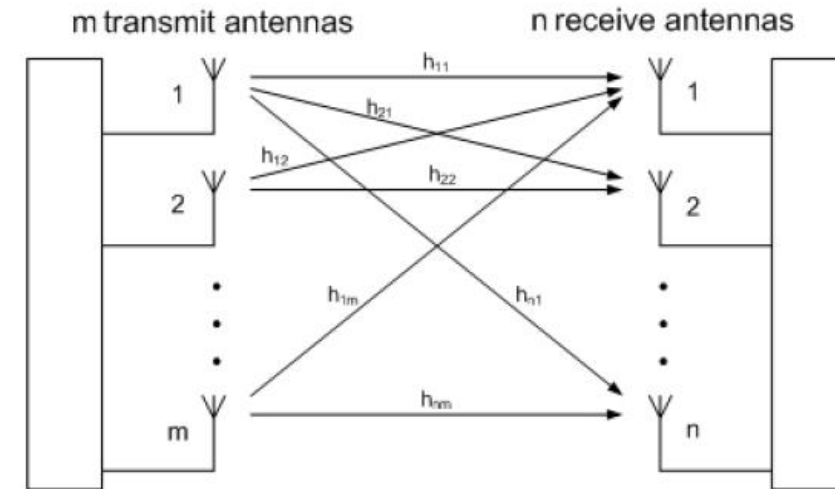


Source:: <https://medium.com/@GeorgeOu/wi-fi-client-sensitivity-is-not-that-volatile-d5a62283c690>

SISO vs MIMO

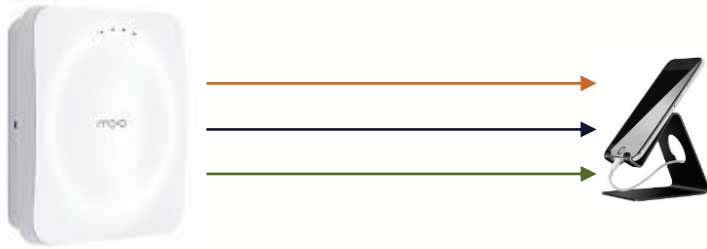


$$C = B \log_2 \left(1 + \frac{S}{N} \right)$$

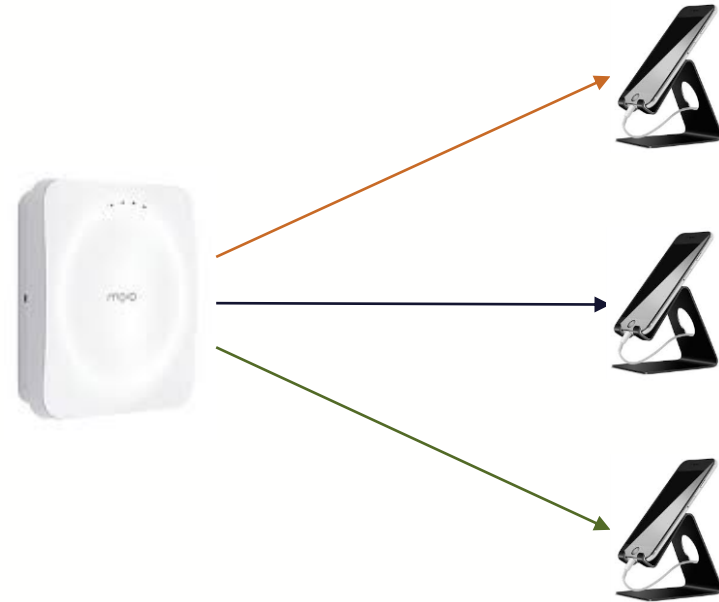


$$C = M B \log_2 \left(1 + \frac{S}{N} \right)$$

MIMO



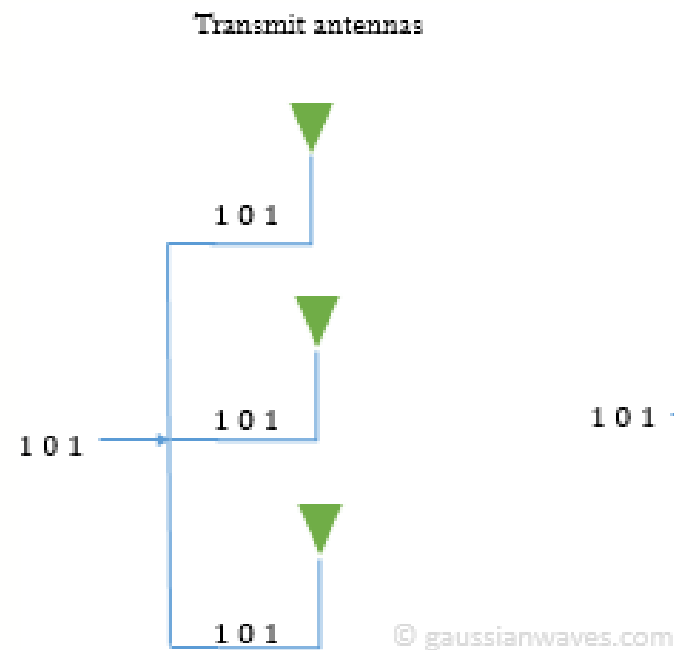
Single User MIMO (SU-MIMO)



Multi User MIMO (MU-MIMO)

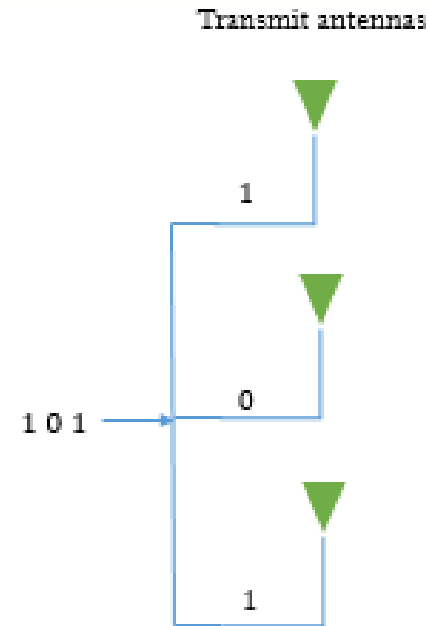
SU-MIMO

- Spatial multiplexing: Transmit independent data streams simultaneously



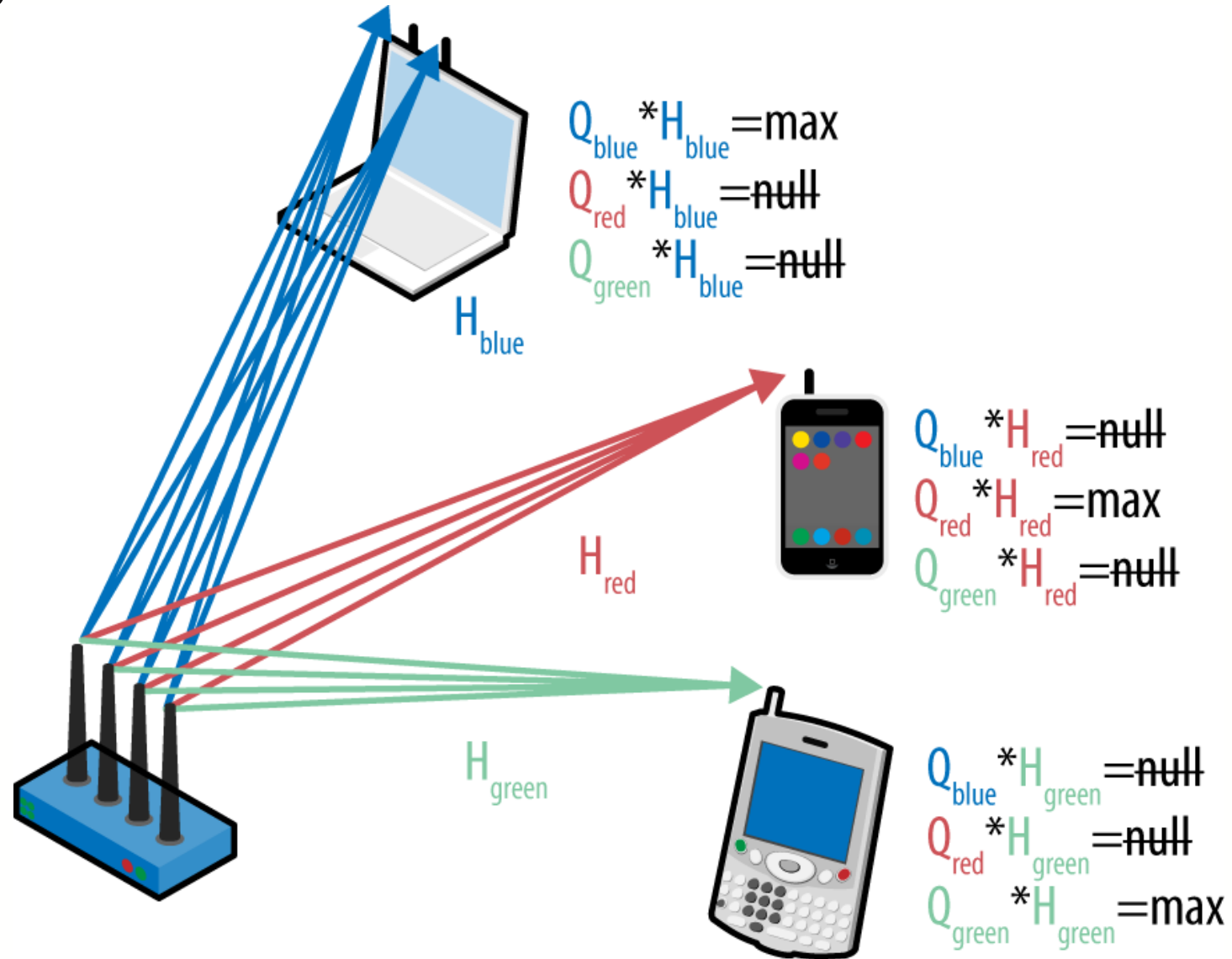
MIMO with Diversity
(Transmit diversity)
Improves reliability

- Spatial diversity: Improve link reliability



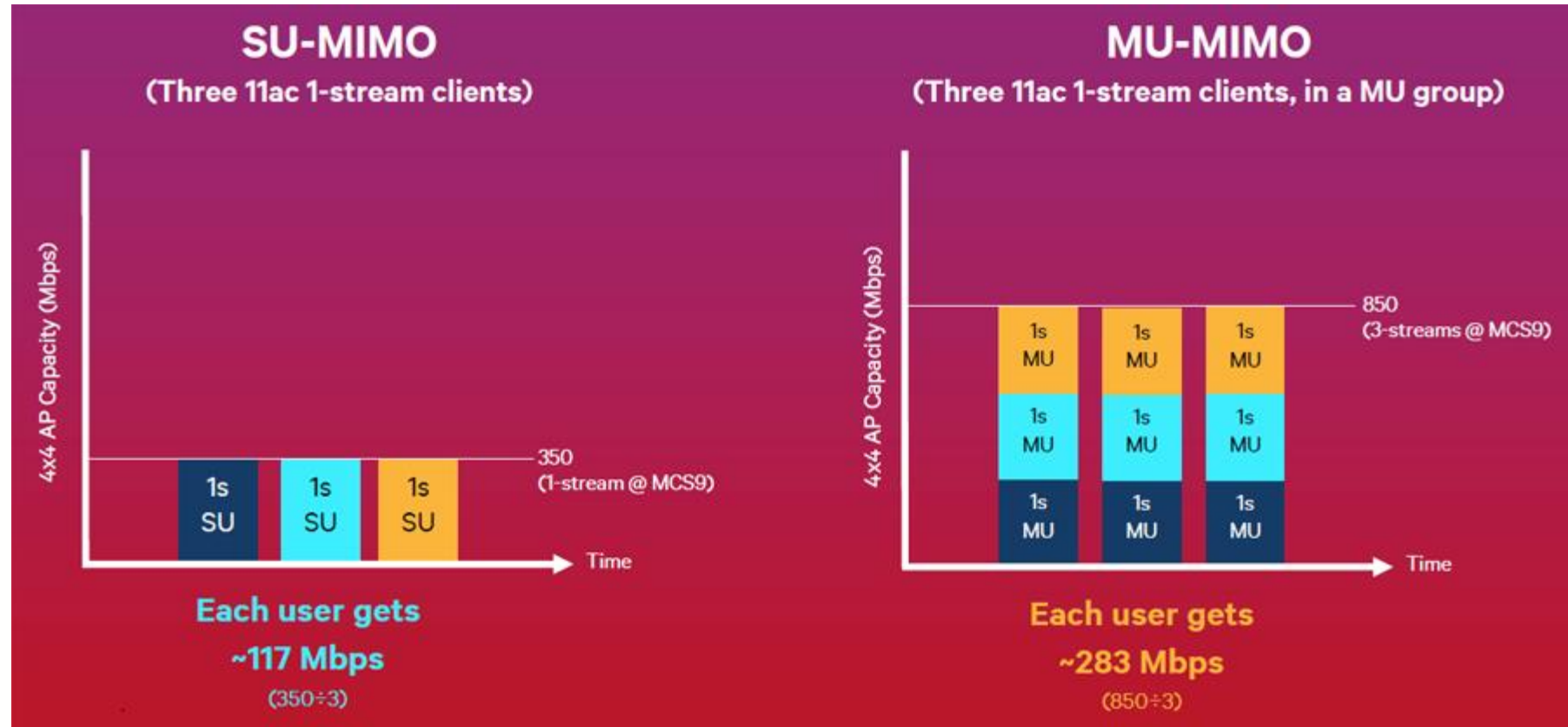
MIMO with
Spatial Multiplexing
Increases data rate

MU-MIMO



Source:: Matthew S Gast, 802.11ac: A Survival Guide

SU-MIMO vs MU-MIMO

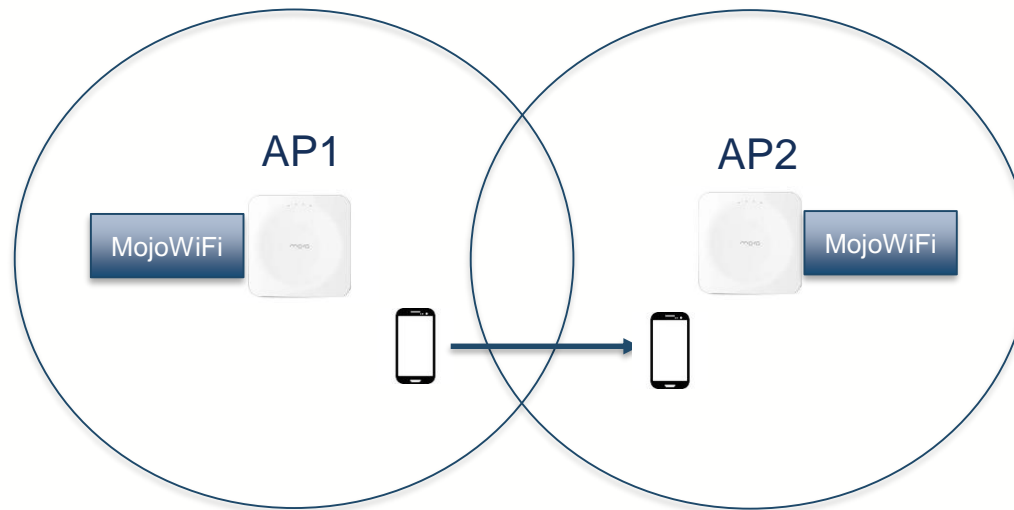


Source:: Qualcomm

Advanced Features

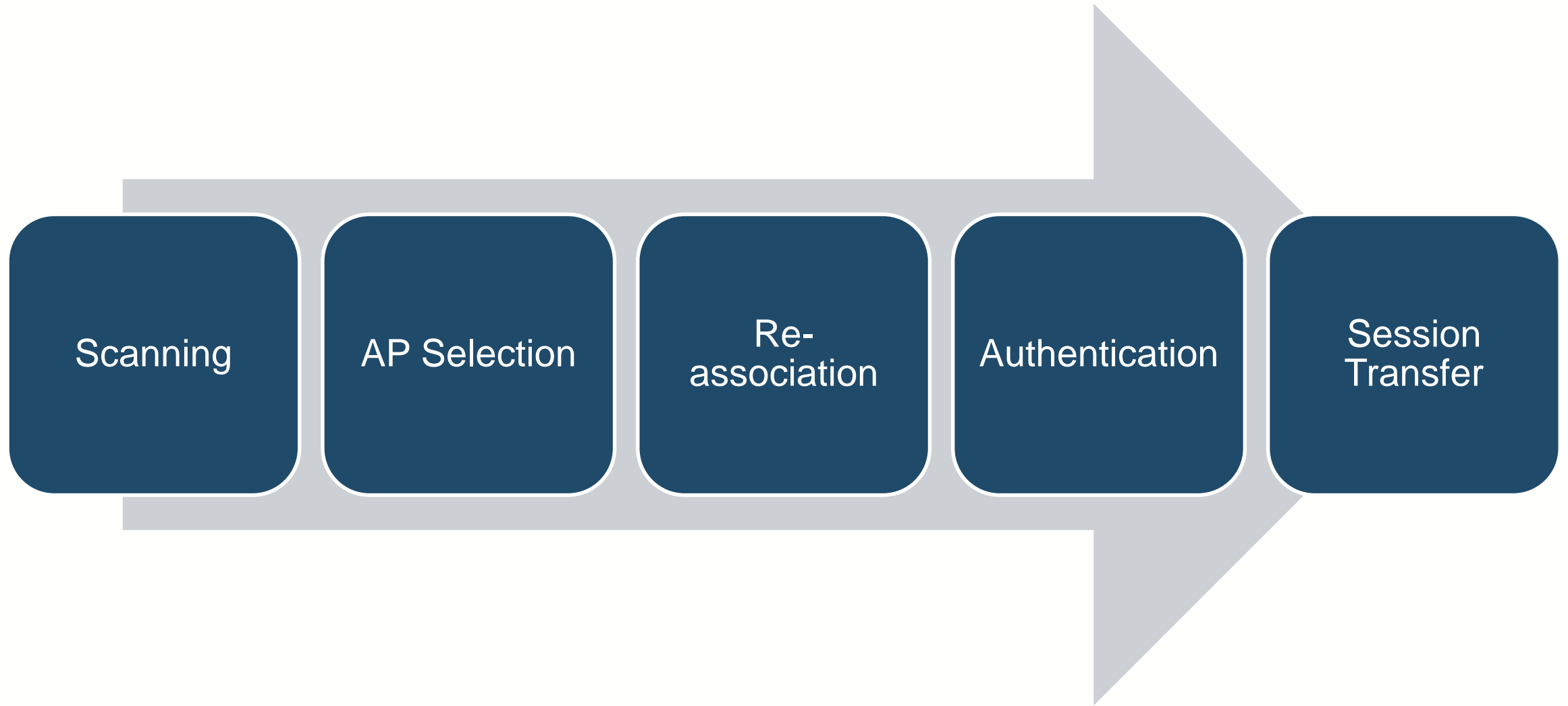
Roaming

- Roaming is the process of a client moving an established Wi-Fi network association from one AP to another access AP without losing connection.

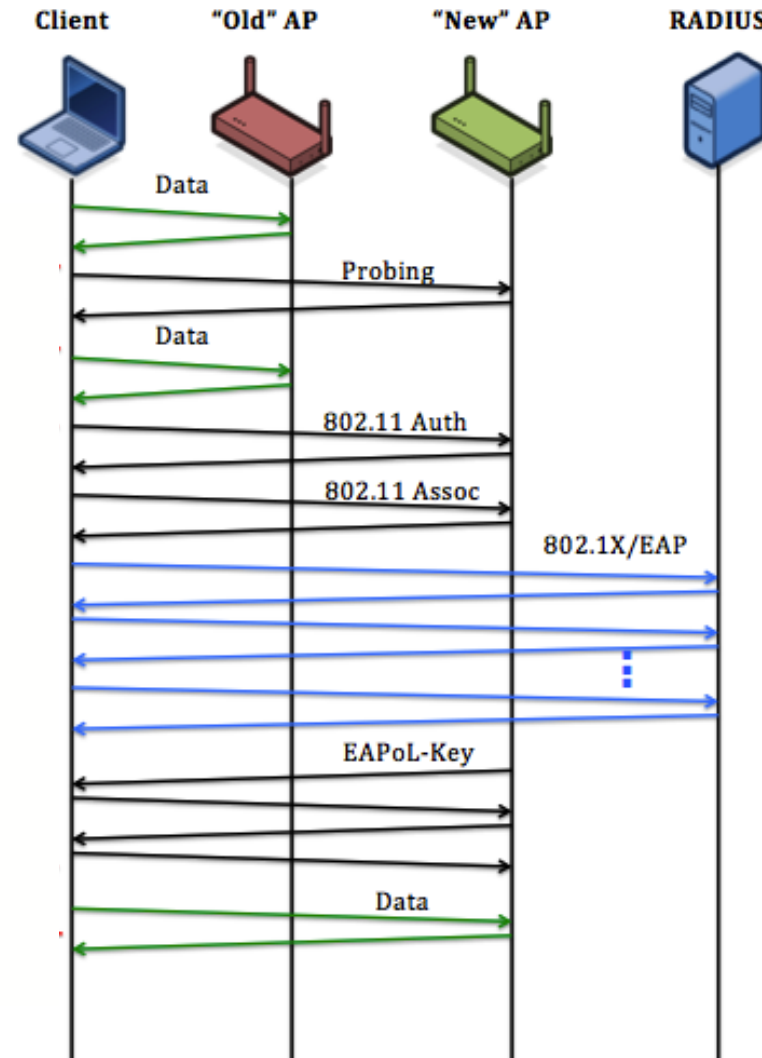


Suggested Reading: WiFi Roaming Revealed, <https://cdn2.hubspot.net/hubfs/353374/CWNP%20signal%20Roaming%20Revealed%20v10.pdf>

Roaming Process



Roaming Call Flow



Source: <http://www.revolutionwifi.net/revolutionwifi/2012/12/wi-fi-roaming-analysis-part-3-measuring.html>

Fast Roaming

PMK Caching

- Pairwise Master Key (PMK) is cached
- If client roams back, fast authentication is available
- 802.1X/EAP can be skipped
- 4-way HS is needed
- Does not help roaming forward

Opportunistic Key Caching

- Vendor driven, non-standardized method
- Original PMK shared with roaming target APs
- If fails, full 802.1X/EAP is used
- Supported quite widely in APs but client side support more variable

802.11 Roaming Enhancements

802.11r (2008)

- **Fast secure roaming with Radius/EAP**
 - A roaming standard
 - No need to authenticate with Radius during roaming
 - Fast, standardized process

802.11v (2011)

- **Wireless Network Management (WNM)**
 - *BSS transition management* the main feature related to roaming
 - Network recommends and assists in roaming decisions

802.11k (2008)

- **Radio resource management**
 - *Neighbor reports* the main feature related to roaming
 - Scan only channels which are used by nearby APs

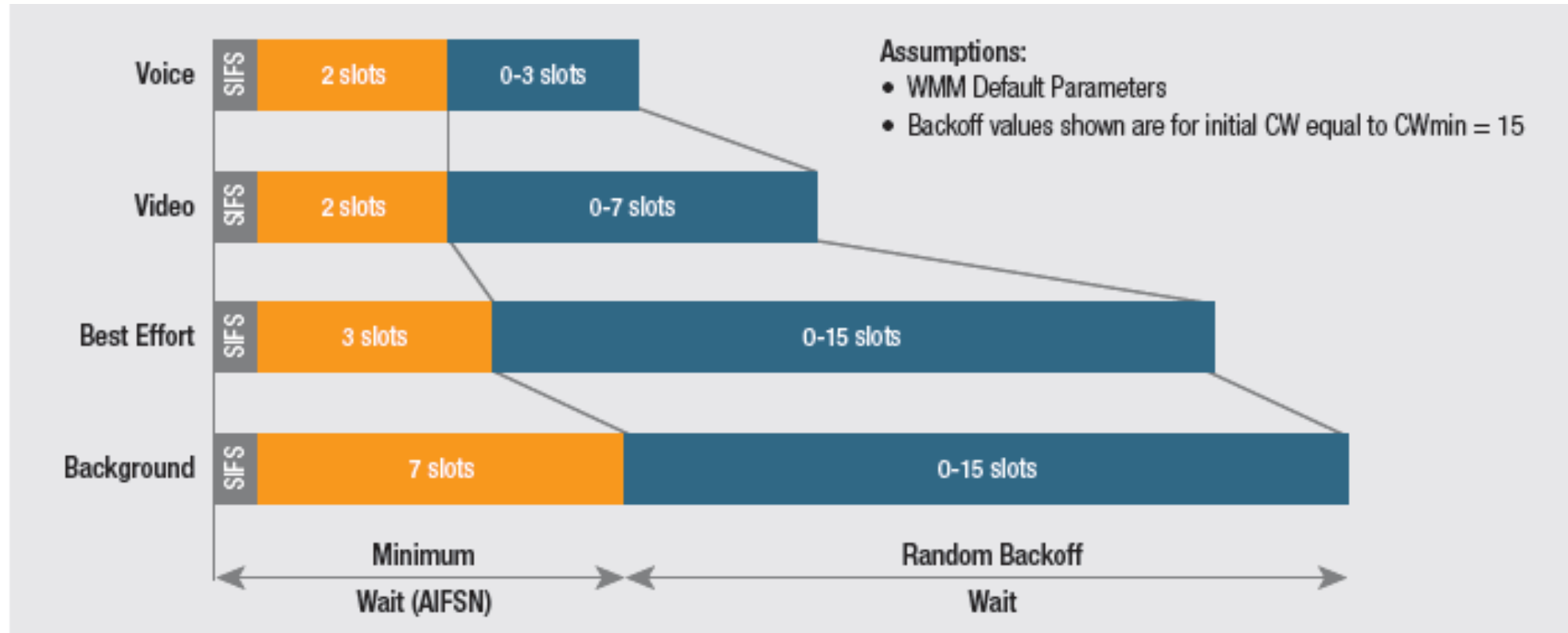
Source: 7 Signals

Quality of Service (QoS)

- WiFi operates in unlicensed spectrum
 - In dense deployments, channels need to be re-used, leading to contention
 - Difficult to guarantee QoS
- IEEE802.11e standard defines a mechanism for prioritizing flows based on class of service
 - Voice
 - Video
 - Best Effort
 - Background

Priority Queues

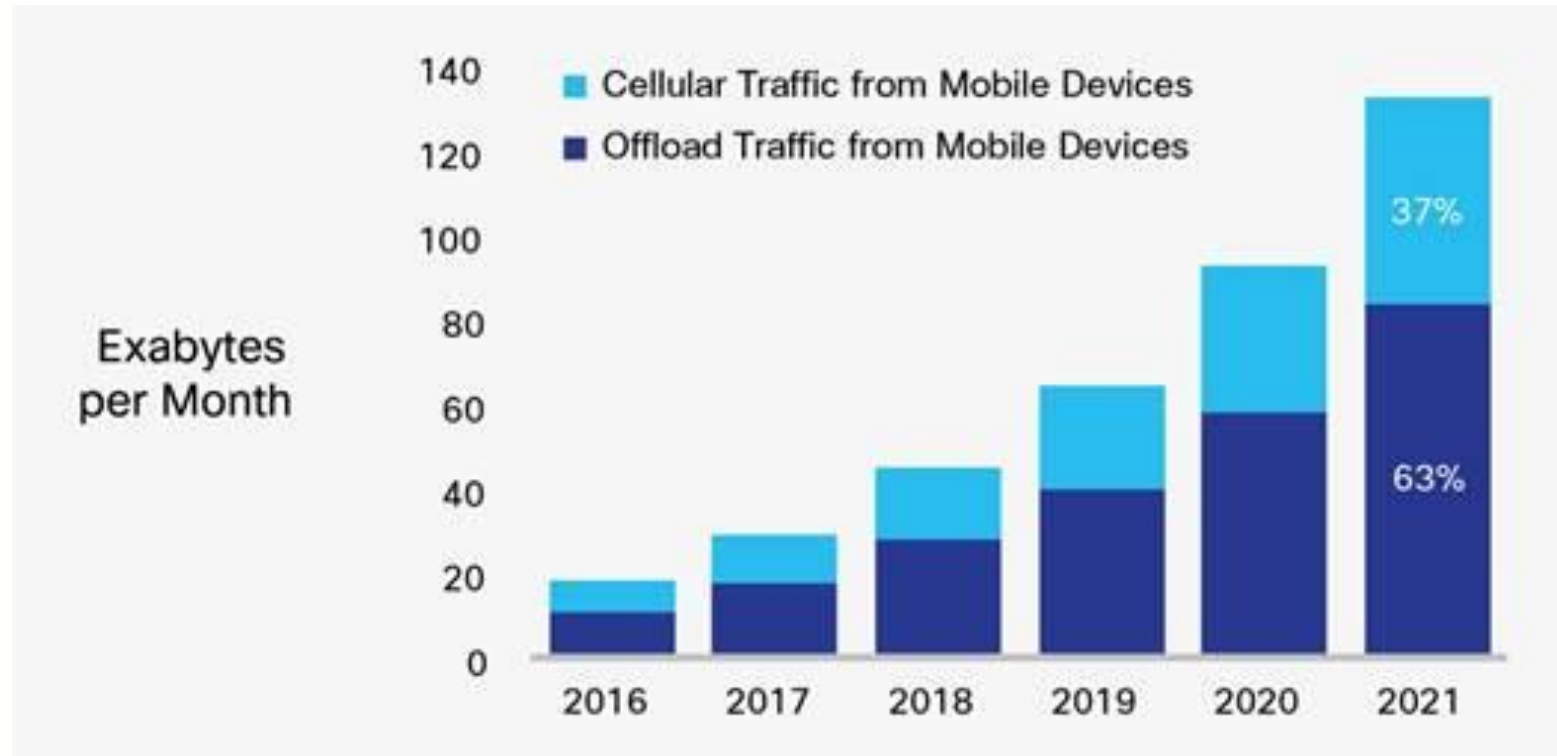
- Wi-Fi multimedia protocol (WMM) adjusts the random back-off timer and the arbitration inter-frame space, according to the QoS priority of the frame to be transmitted.
- High-priority frames are assigned shorter random back-off timers and arbitration inter-frame spaces, while lower priority frames must wait longer.



WiFi Offload

WiFi Offload

- Telecom operators are increasingly leveraging WiFi to augment network capacity
 - WiFi based offload
 - VoWiFi / WiFi Calling



Source: Cisco VNI 2017

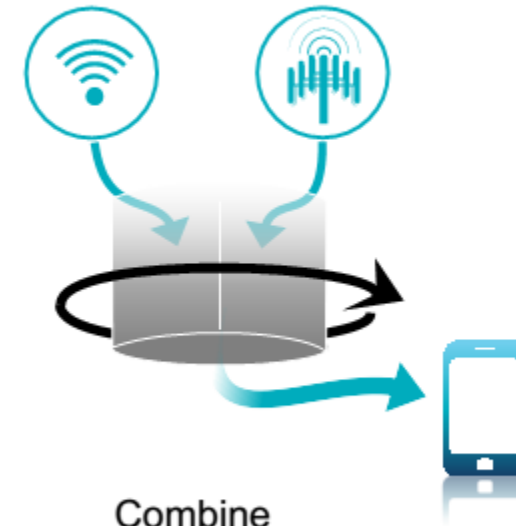
Cellular-WiFi Interworking



Convergence of
Cellular and Wi-Fi
Infrastructure



Seamless Access
and Connectivity

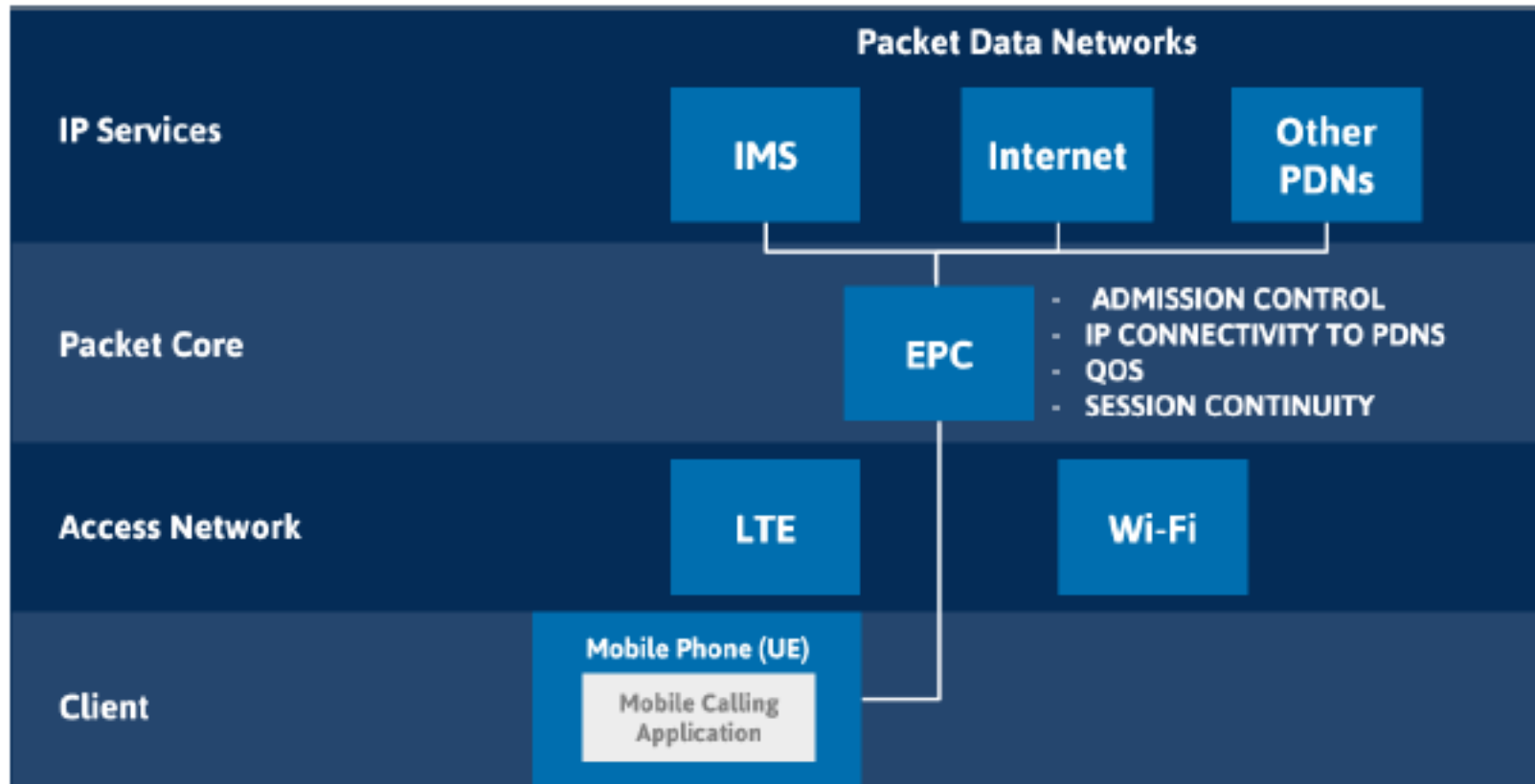


Combine
Wi-Fi and 3G/4G

Source: Qualcomm

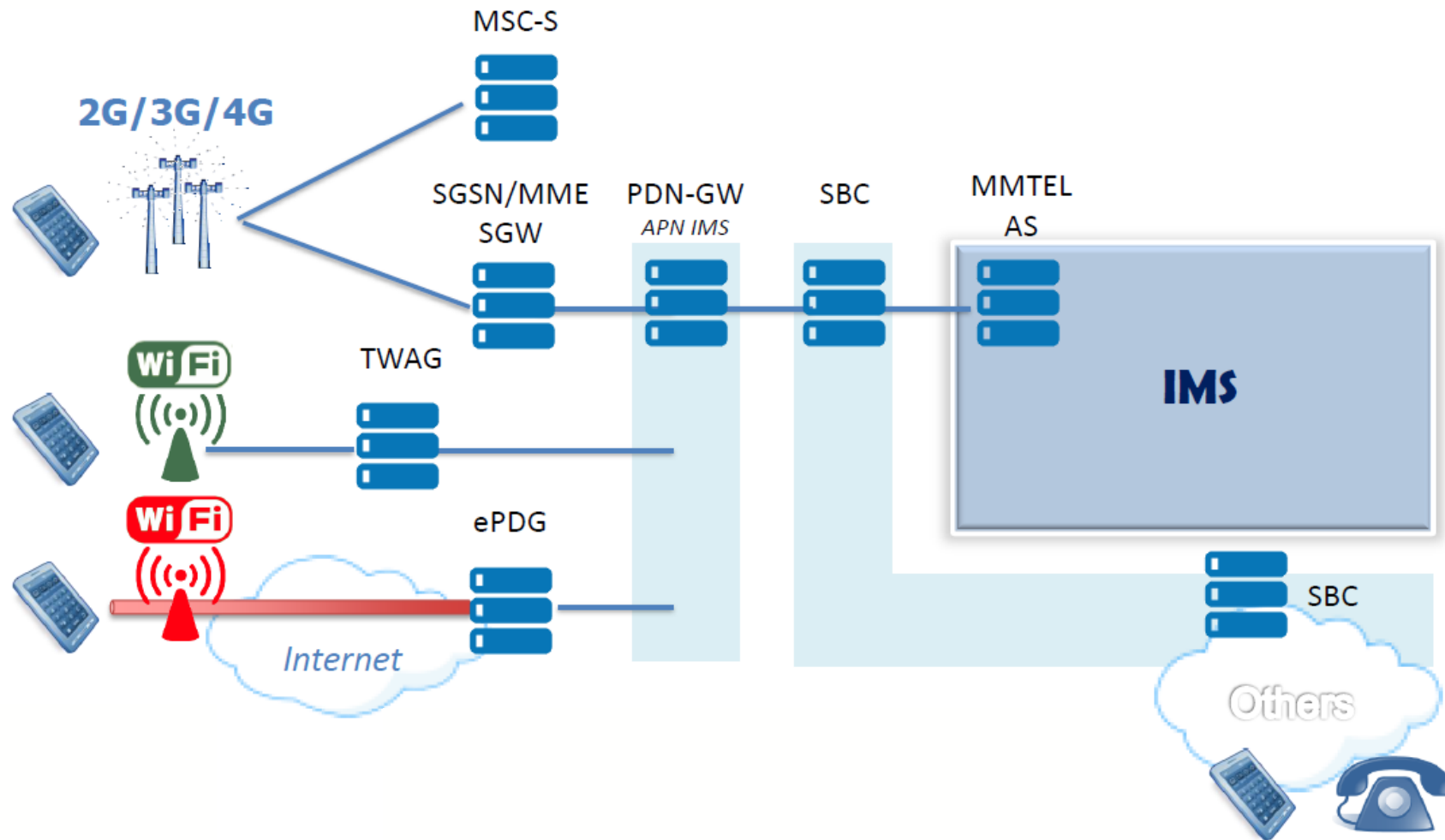
VoWiFi

- Voice over WiFi is a standards-based to provide carrier-grade voice over WiFi networks using the Evolved Packet Core of 4G-LTE network



Source: WBA

VoWiFi Architecture



Q & A