

WIFI 6 - MORE THAN JUST SPEEDS IT'S ABOUT EFFICIENCY AND DENSITY

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HTE Rádiótávközlési Szakosztály rendezvény

Budapest 2021. március 29





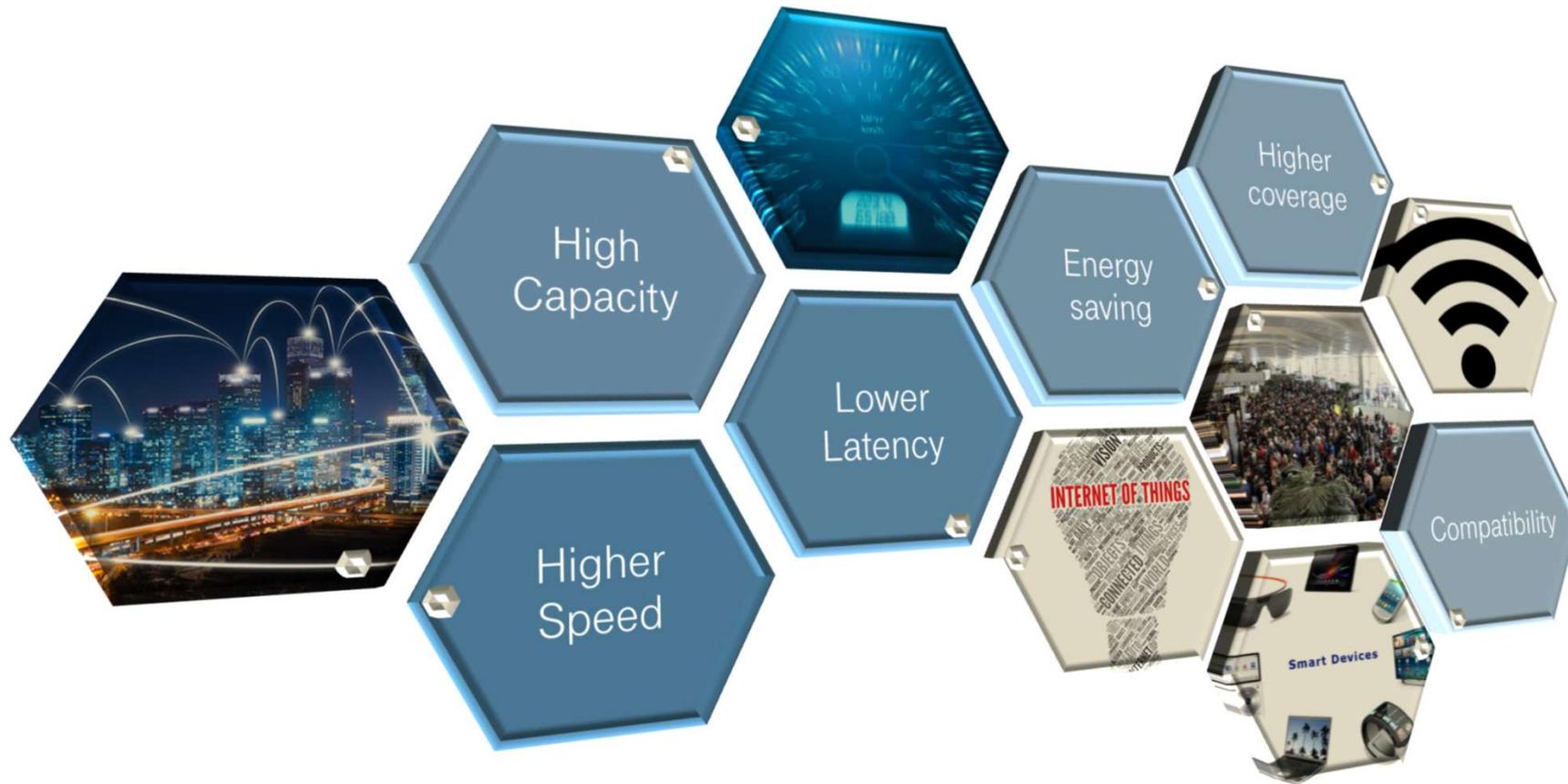
Main drivers of Wi-Fi6

Key Technologies

WiFi6 & 5G

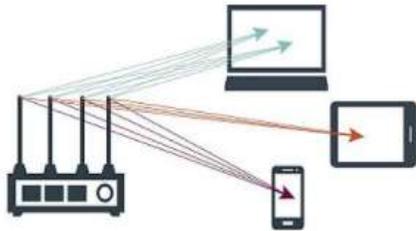
Market overview

WIFI EVOLUTION – INITIALLY THE SPEED WAS IN THE FOCUS NOW THE EFFICIENCY AND OPERATION IN DENSE ENVIRONMENT

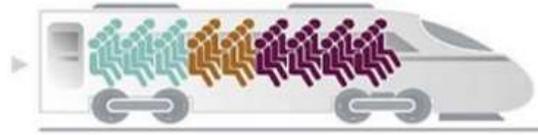


Wi-Fi CERTIFIED 6™ key features

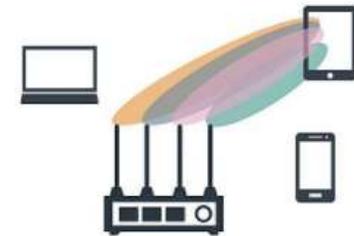
Multi-User MIMO



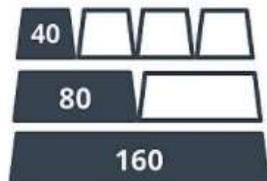
OFDMA



Beamforming



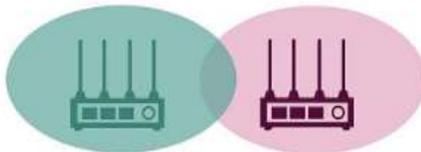
160 MHz Channel Bandwidth



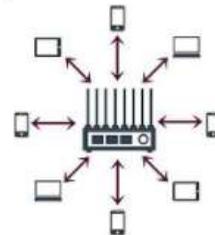
Target Wake Time



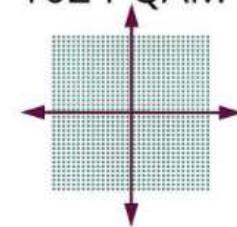
BSS Coloring



8 Spatial Streams



1024-QAM

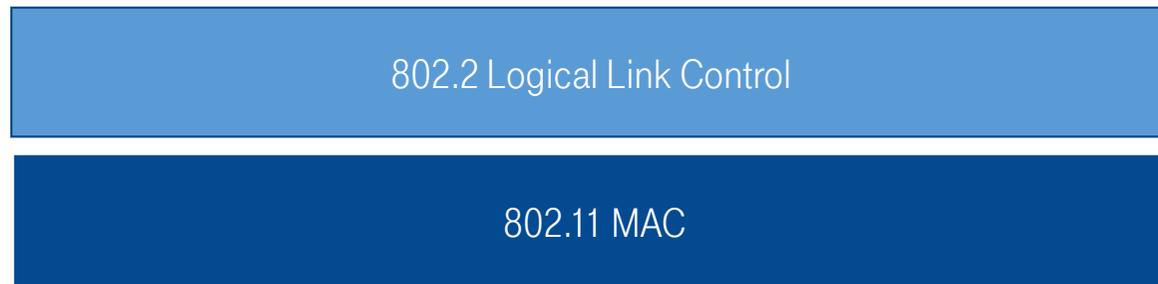


The background features a complex network of glowing blue lines and nodes, resembling a digital or molecular structure. A bright blue light source is visible on the right side, casting a glow across the network. The overall color palette is dominated by deep blues and bright cyan, with some orange and red highlights in the lower-left quadrant.

TECHNOLOGY

IEEE 802.11 STANDARDS AND OSI MODEL

MAC layer is common to all 802.11 Physical layer (PHY) standards



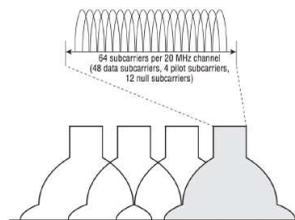
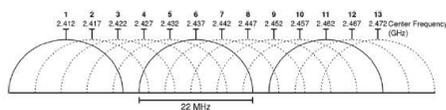
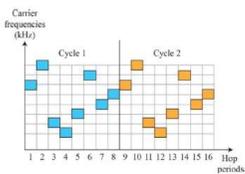
Data Link Layers

LLC sublayers

MAC sublayer

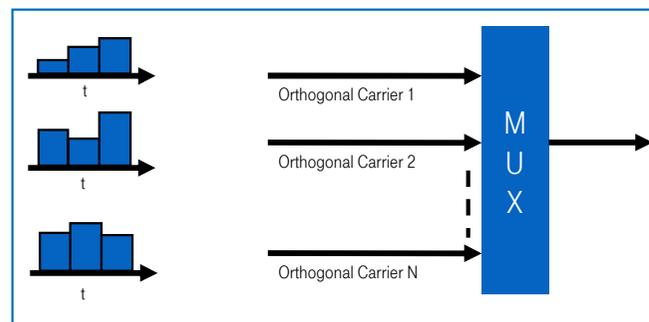
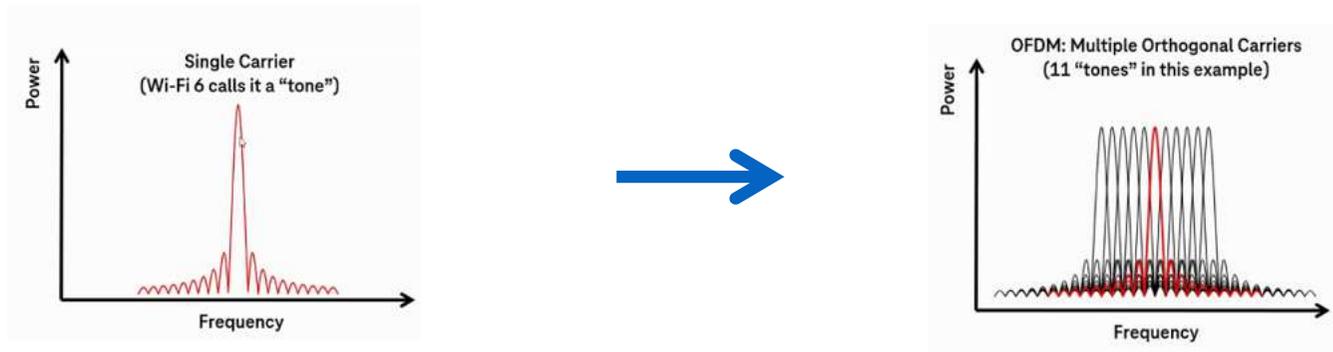


PHY layer



OFDM (ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING)

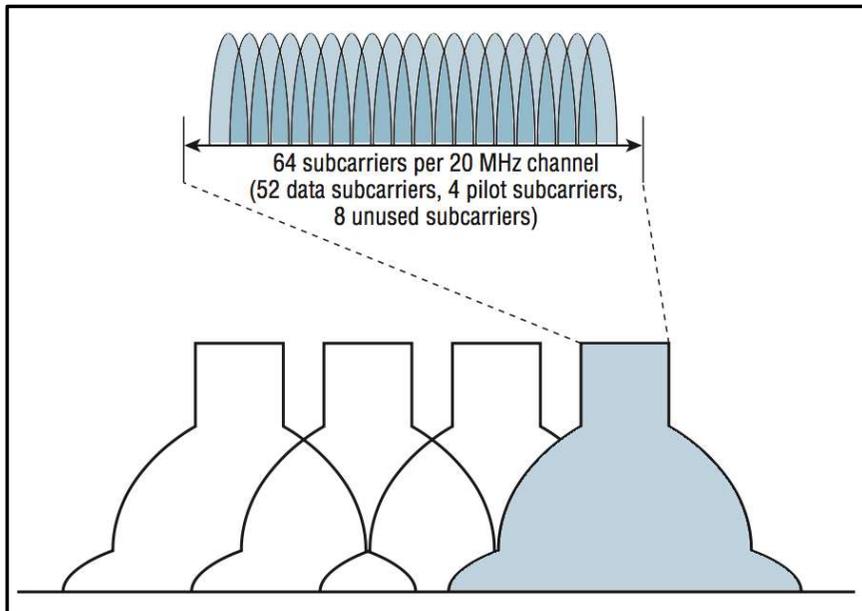
With OFDM, data is transmitted over multiple orthogonal carriers. The carriers are orthogonal (they are spaced such that their sideband are aligned and do not interfere with the carriers' center frequencies)



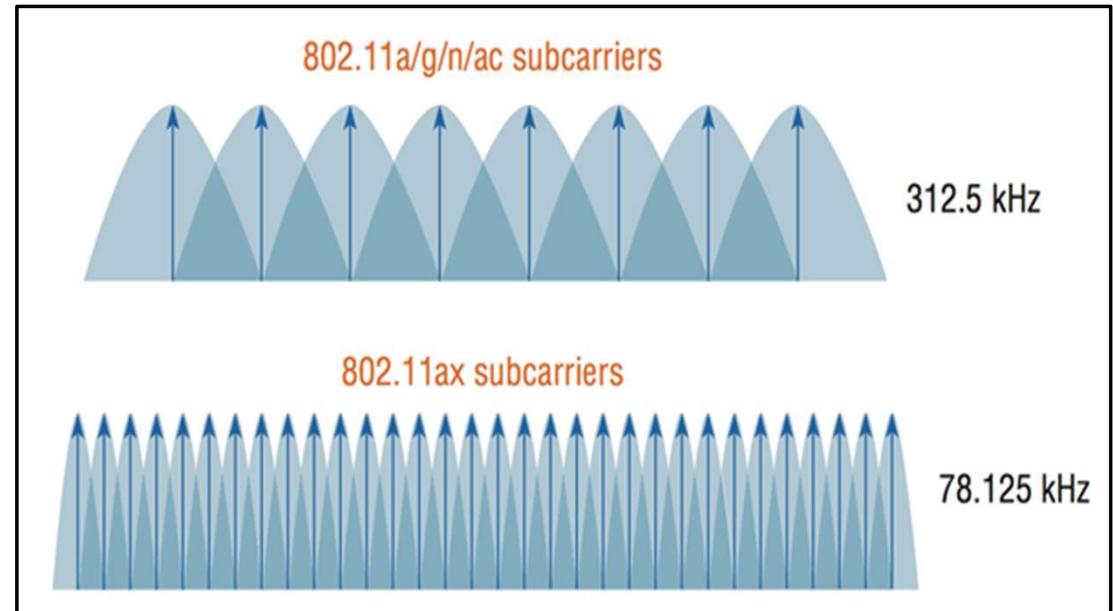
OFDM/OFDMA SUBCARRIERS

The narrow subcarrier spacing allows better equalization and therefore enhanced channel robustness.

802.11n/ac/ax 20 MHz channel—OFDM subcarriers



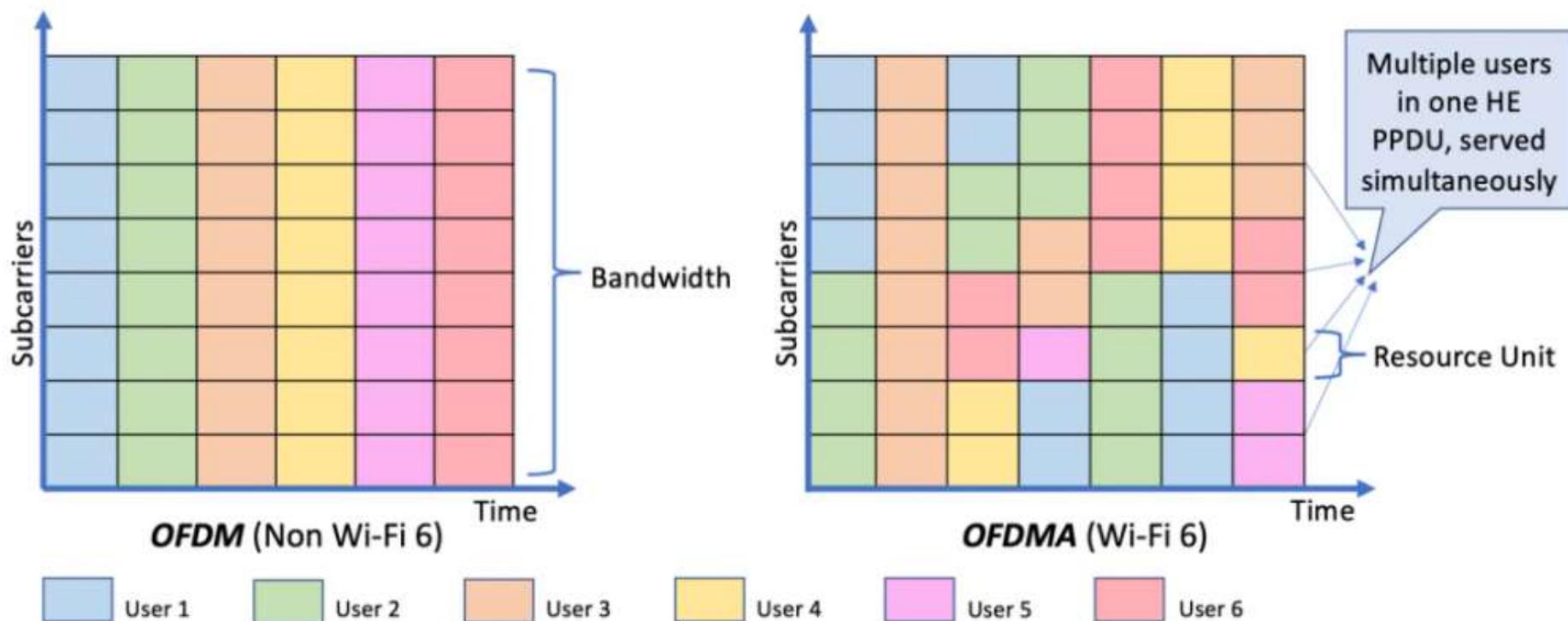
OFDM/OFDMA subcarriers spacing



OFDMA symbol time : 12.8 μ s

OFDM symbol time: 3.2 μ s

OFDM ALLOWS SINGLE USER TRANSMISSION WHILE OFDMA USES RUs THAT CAN BE INDIVIDUALLY ASSIGNED TO STA (CLIENT)

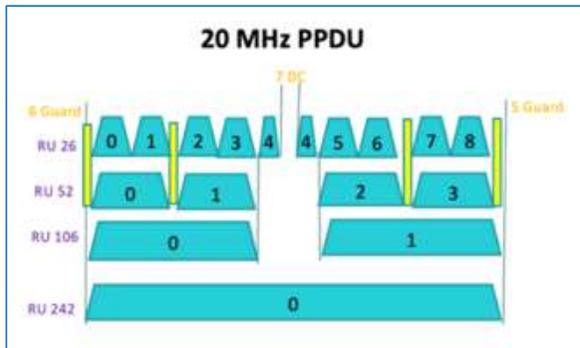


RESOURCE UNIT MAP

A STA CAN ONLY BE ASSIGNED TO ONE RU AT A TIME

| Bandwidth | Tones WiFi6 | Tones WiFi5 |
|-----------|-------------|-------------|
| 20MHz | 256 | 64 |
| 40MHz | 512 | 128 |
| 80MHz | 1024 | 256 |
| 160MHz | 2048 | 512 |

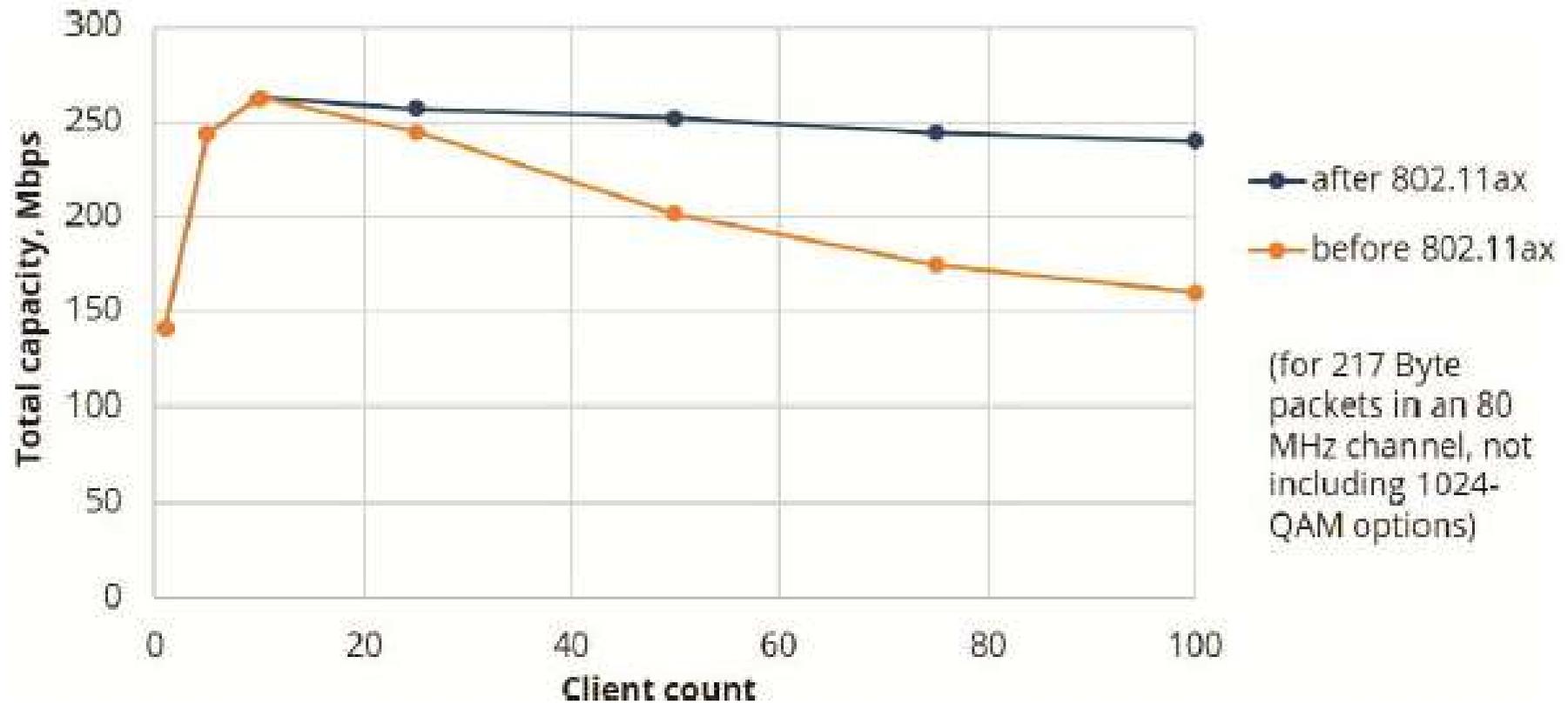
| RU type | 20MHz | 40MHz | 80MHz | 80+80/160MHz |
|---------------|-------|-------|-------|--------------|
| 26-tone RU | 9 | 18 | 37 | 74 |
| 52-tone RU | 4 | 8 | 16 | 32 |
| 106-tone RU | 2 | 4 | 8 | 16 |
| 242-tone RU | 1 | 2 | 4 | 8 |
| 48-toneRU | N/A | 1 | 2 | 4 |
| 996-tone RU | N/A | N/A | 1 | 2 |
| 2x996-tone RU | N/A | N/A | N/A | 1 |



Some Tones are used for DC (direct conversion), Guard and unused (Null Sub carriers) tones.

THROUGHPUT VS STA NUMBER WITH SMALL PACKETS

NO SIGNIFICANT PERFORMANCE DEGRADATION



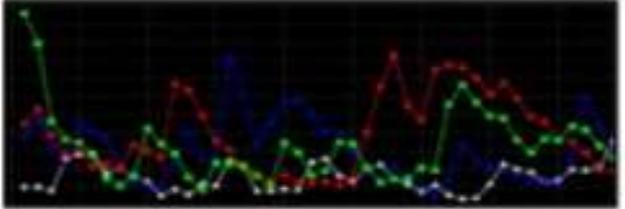
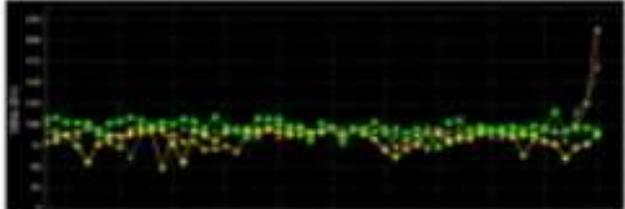
STABLE TCP THROUGHPUT WITH LOW LATENCY (<5 ms) USING OFDMA

■ Test environment

- 4 Smartphones (Wi-Fi6)

■ Performance Results

- Latency is reduced by about 80%
- Throughput fluctuation per user is reduced
- Throughput about 1 G (2SS, 80MHz, 1024QAM)

| | Latency | Throughput Variation per user |
|-----------|---------|--|
| w/o OFDMA | 21 ms |  |
| w/ OFDMA | 4 ms |  |

Source: SK telekom

MCS INDEX – WHY SO DIFFICULT TO DETERMINE THE WI-FI SPEED

The Modulation Coding Scheme (MCS) index is a metric based on several parameters of a WiFi connection between two stations.

www.mcsindex.com

Math behind it

$$\text{Data Rate} = \frac{N_{SD} * N_{BPSCS} * R * N_{SS}}{T_{DFT} + T_{GI}}$$

Number of Data Subcarriers N_{SD} Number of Coded Bits per Subcarrier per Stream N_{BPSCS} Coding R Number of Spatial Streams N_{SS}
OFDM Symbol Duration T_{DFT} Guard Interval Duration T_{GI}

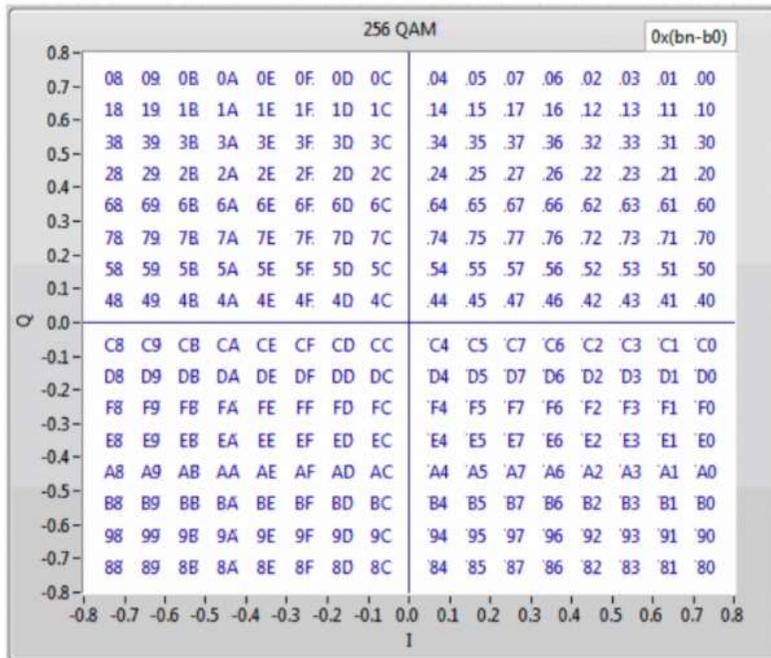
| | | | | | | OFDM (Prior 11ax) | | | | | | | |
|-----------|-----|----|----------------|------------|--------|-------------------|----------|----------|----------|----------|----------|----------|----------|
| MCS Index | | | Spatial Stream | Modulation | Coding | 20MHz | | 40MHz | | 80MHz | | 160MHz | |
| HT | VHT | HE | | | | 0.8µs GI | 0.4µs GI | 0.8µs GI | 0.4µs GI | 0.8µs GI | 0.4µs GI | 0.8µs GI | 0.4µs GI |
| 0 | 0 | 0 | 1 | BPSK | 1/2 | 6.5 | 7.2 | 13.5 | 15 | 29.3 | 32.5 | 58.5 | 65 |
| 1 | 1 | 1 | 1 | QPSK | 1/2 | 13 | 14.4 | 27 | 30 | 58.5 | 65 | 117 | 130 |
| 2 | 2 | 2 | 1 | QPSK | 3/4 | 19.5 | 21.7 | 40.5 | 45 | 87.8 | 97.5 | 175.5 | 195 |
| 3 | 3 | 3 | 1 | 16-QAM | 1/2 | 26 | 28.9 | 54 | 60 | 117 | 130 | 234 | 260 |
| 4 | 4 | 4 | 1 | 16-QAM | 3/4 | 39 | 43.3 | 81 | 90 | 175.5 | 195 | 351 | 390 |
| 5 | 5 | 5 | 1 | 64-QAM | 2/3 | 52 | 57.8 | 108 | 120 | 234 | 260 | 468 | 520 |
| 6 | 6 | 6 | 1 | 64-QAM | 3/4 | 58.5 | 65 | 121.5 | 135 | 263.3 | 292.5 | 526.5 | 585 |
| 7 | 7 | 7 | 1 | 64-QAM | 5/6 | 65 | 72.2 | 135 | 150 | 292.5 | 325 | 585 | 650 |
| | 8 | 8 | 1 | 256-QAM | 3/4 | 78 | 86.7 | 162 | 180 | 351 | 390 | 702 | 780 |
| | 9 | 9 | 1 | 256-QAM | 5/6 | N/A | N/A | 180 | 200 | 390 | 433.3 | 780 | 866.7 |
| | | 10 | 1 | 1024-QAM | 3/4 | | | | | | | | |
| | | 11 | 1 | 1024-QAM | 5/6 | | | | | | | | |
| 8 | 0 | 0 | 2 | BPSK | 1/2 | 13 | 14.4 | 27 | 30 | 58.5 | 65 | 117 | 130 |
| 9 | 1 | 1 | 2 | QPSK | 1/2 | 26 | 28.9 | 54 | 60 | 117 | 130 | 234 | 260 |
| 10 | 2 | 2 | 2 | QPSK | 3/4 | 39 | 43.3 | 81 | 90 | 175.5 | 195 | 351 | 390 |
| 11 | 3 | 3 | 2 | 16-QAM | 1/2 | 52 | 57.8 | 108 | 120 | 234 | 260 | 468 | 520 |
| 12 | 4 | 4 | 2 | 16-QAM | 3/4 | 78 | 86.7 | 162 | 180 | 351 | 390 | 702 | 780 |
| 13 | 5 | 5 | 2 | 64-QAM | 2/3 | 104 | 115.6 | 216 | 240 | 468 | 520 | 936 | 1040 |
| 14 | 6 | 6 | 2 | 64-QAM | 3/4 | 117 | 130 | 243 | 270 | 526.5 | 585 | 1053 | 1170 |
| 15 | 7 | 7 | 2 | 64-QAM | 5/6 | 130 | 144.4 | 270 | 300 | 585 | 650 | 1170 | 1300 |
| | 8 | 8 | 2 | 256-QAM | 3/4 | 156 | 173.3 | 324 | 360 | 702 | 780 | 1404 | 1560 |
| | 9 | 9 | 2 | 256-QAM | 5/6 | N/A | N/A | 360 | 400 | 780 | 866.7 | 1560 | 1733.3 |

The image features a complex, glowing network of interconnected nodes and lines, resembling a molecular structure or a data grid. The nodes are small, bright blue spheres, and the lines are thin, glowing blue lines. The overall color palette is dominated by deep blues and vibrant oranges, set against a dark, almost black background. The network appears to be expanding or contracting, creating a sense of dynamic movement. In the lower-left corner, the word "MODULATION" is written in a bold, white, sans-serif font.

MODULATION

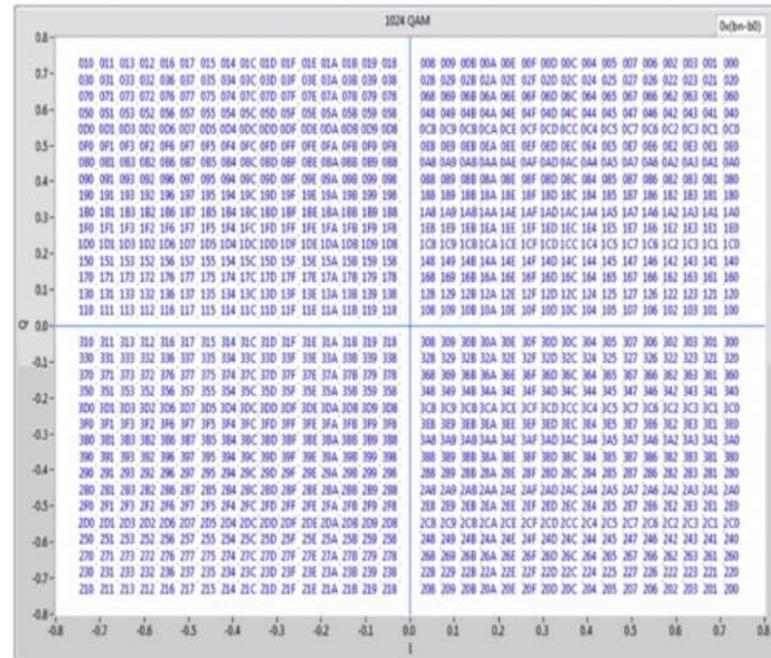
25% INCREASEMENT IN PHY DATA RATE USING 1024 QAM

11ac – 256 QAM
8 bits per symbol



TX EVM MCS9 = -32 dB
Min Sens MCS9 (20 MHz, 80 MHz) = -57, -51 dBm

11ax – 1024 QAM
10 bits per symbol

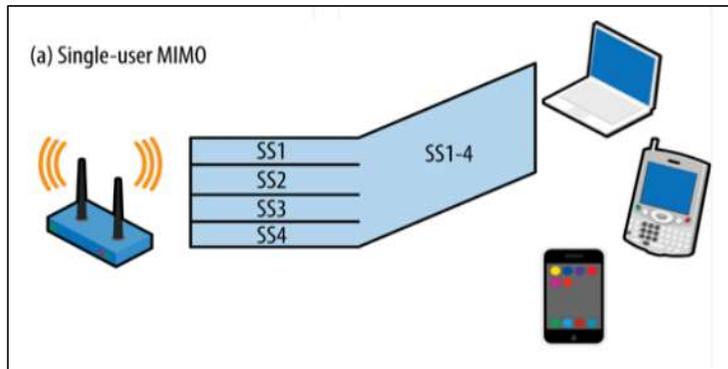


TX EVM MCS11 = -35 dB
Min Sens MCS11 (20 MHz, 80 MHz) = -52, -46 dBm

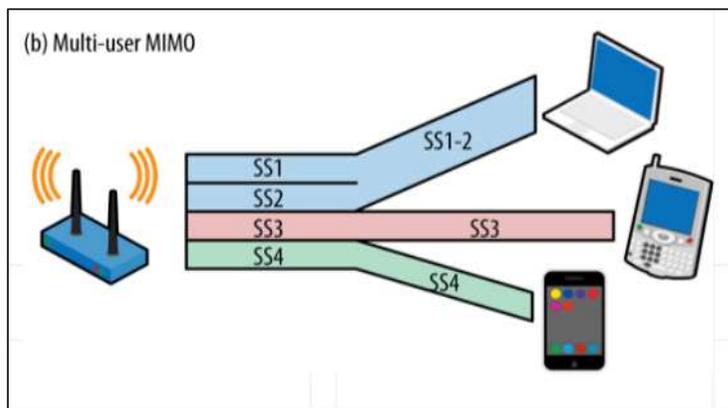


MULTIUSER MI-MO

MIMO/MU-MIMO TECHNOLOGIES



- Single User MIMO (Multiple Input – Multiple Output) allows the AP to send data via several antennas to **ONE** client
- Data is splitted to parallel streams
- Client needs to provide several antennas as well

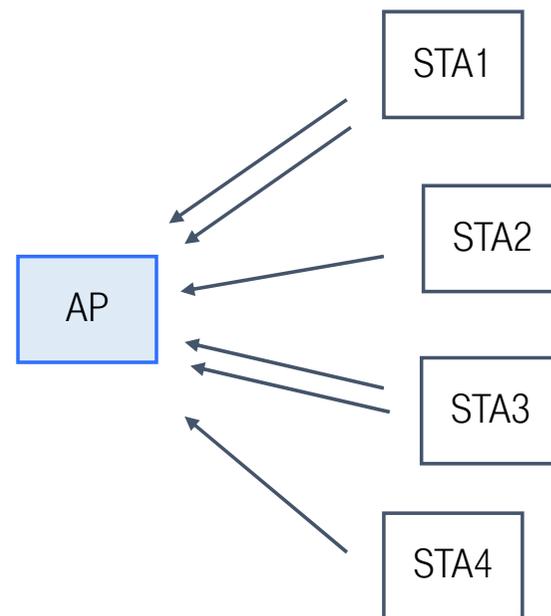
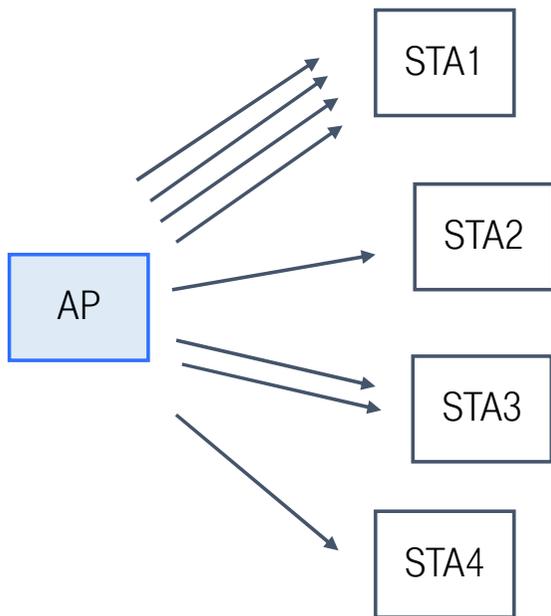


- Multi User MIMO (Multiple Input – Multiple Output) allows the AP to send data via several antennas to **SEVERAL** client
- MU-MIMO utilises „beamforming”, a technology that allows to focus the electric signal locally to a certain device,
- Available from Wi-Fi5 but optional
- Same MCS should be used by all STA

UPLINK MULTI-USER MIMO (UL MU-MIMO)

WiFi5: Downlink MU-MIMO
Max 8 SS @DS

WiFi6: Downlink + Uplink MU-MIMO
Max 8SS@DS and 4SS@US

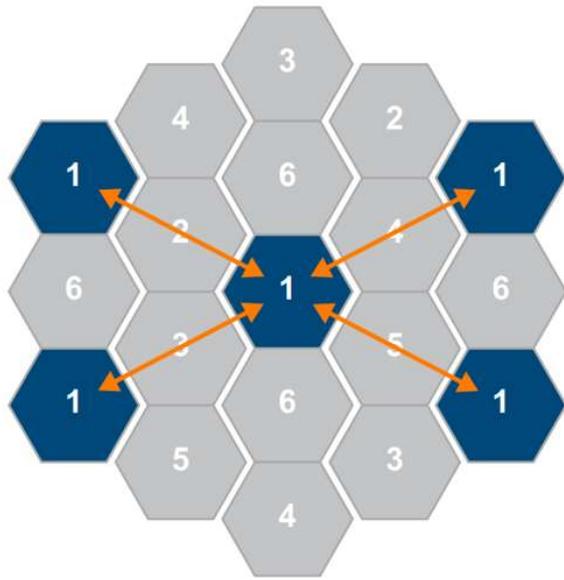


MU-MIMO should be supported by both AP and STA.
MU-MIMO with Wi-Fi6 works in both 2.4 GHz & 5GHz (DS:8, UL:4).
SS depends on the number of antennas (2x2:2, 3x3:3, 4x4:2 etc)

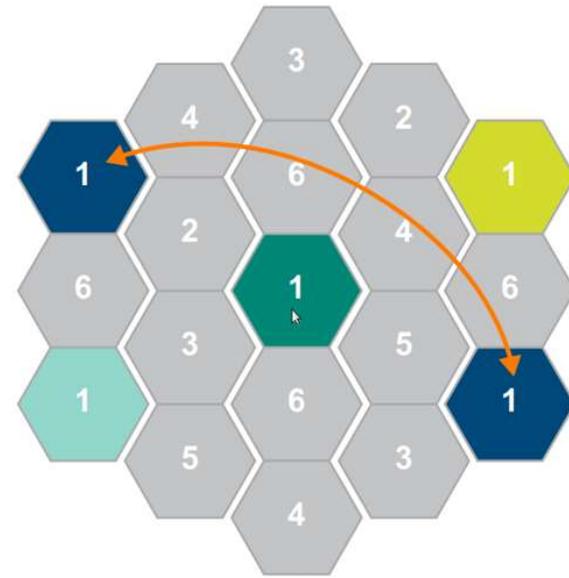


BSS COLORING

BSS COLORING REDUCES INTERFERENCE AMONG DEVICES USING THE SAME CHANNELS



Without BSS coloring, all overlapping channels interfere



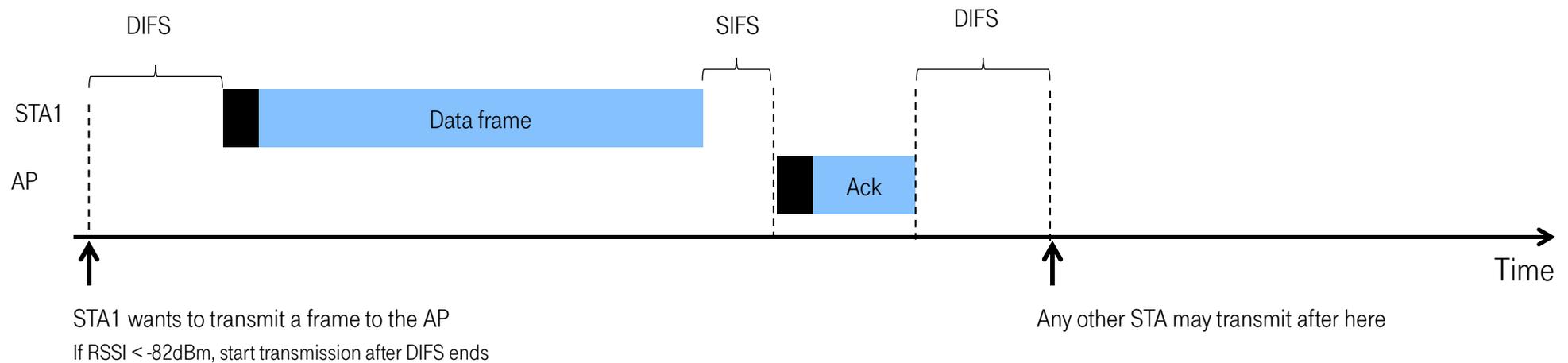
With BSS coloring only matching colors interfere

802.11 MEDIUM ACCESS CONTROL

Wireless LAN is using CSMA/CA (Carrier Sense Multiple Access/Collision Avoidance) as medium access control scheme

Before transmission, a STA has to sense that the channel is free (DIFS (DCF Inter-Frame Space, 34 us))

It may then send the frame and expects an ACK from the receiving STA after a SIFS (Short Inter-Frame Space, 16us)



802.11 MEDIUM ACCESS CONTROL (2)

In case a STA sense the transmission of another STA during DIFS, it has to wait until the transmission is over.

Then it waits for another DIFS plus a random duration

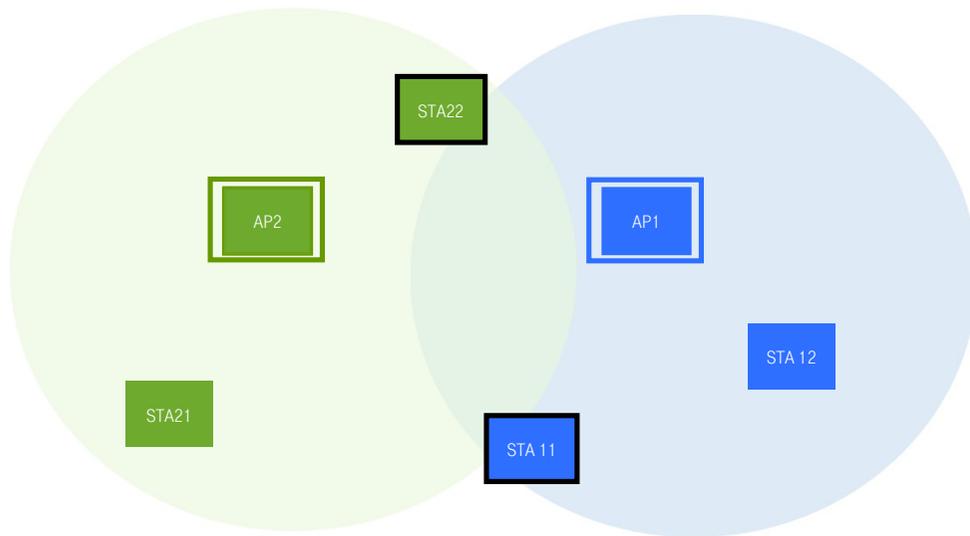


BSS COLORING

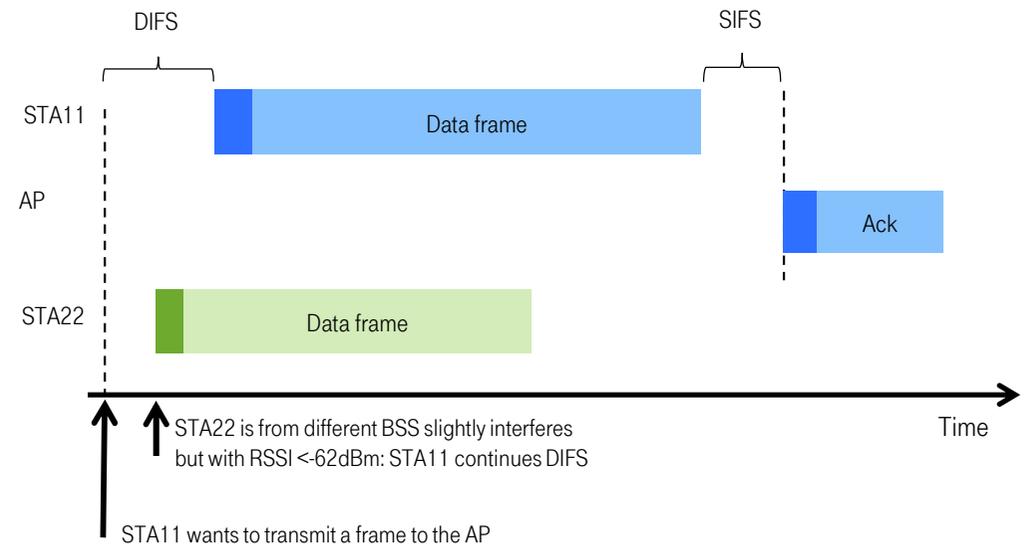
With Wi-Fi6 BSS Coloring each AP is automatically assigned a value in the range 1-63 („color”), which is included in the preamble of each frame of the AP and its STA in the BSS.

When waiting a DIFS, a STA ignores frames of other STAs that have a different color and the RSSI is less than -62dBm.

This increases the density in which Wi-Fi6 network can be deployed.



Two Aps with different colors and slightly overlapping ranges



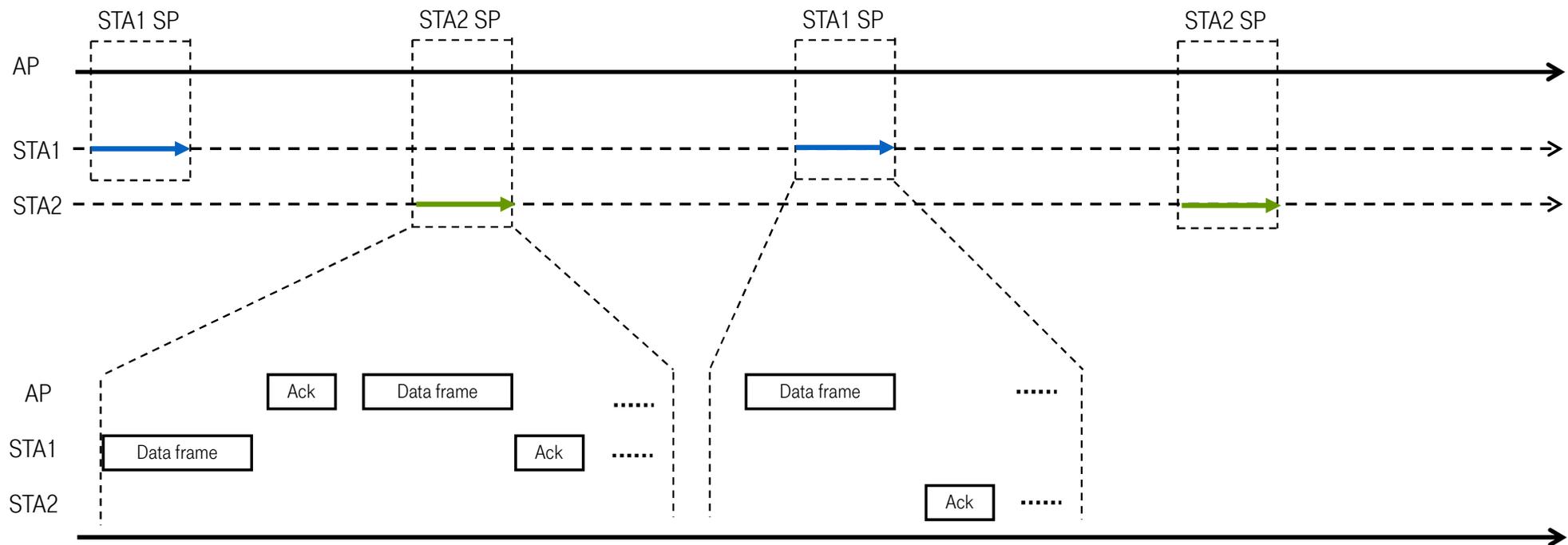
The background features a complex, glowing grid of blue lines and nodes, resembling a network or data structure. The grid is set against a dark blue background with scattered orange and yellow light spots, suggesting a digital or space-themed environment. A bright blue light source is visible on the right side, creating a lens flare effect.

TARGET WAKE TIME

TARGET WAKE TIME („DRX FOR WI-FI) SAVES BATTERY

AP and STA may define periodical Service Periods (SP).

During a SP a STA may send or receive frames. Outside the SP the STA sleeps. This saves battery.





WI-FI IN REAL ENVIRONMENT

PERFORMANCE

40% BOOSTED SPEED ON WIFI 6 COMPARE TO WIFI5

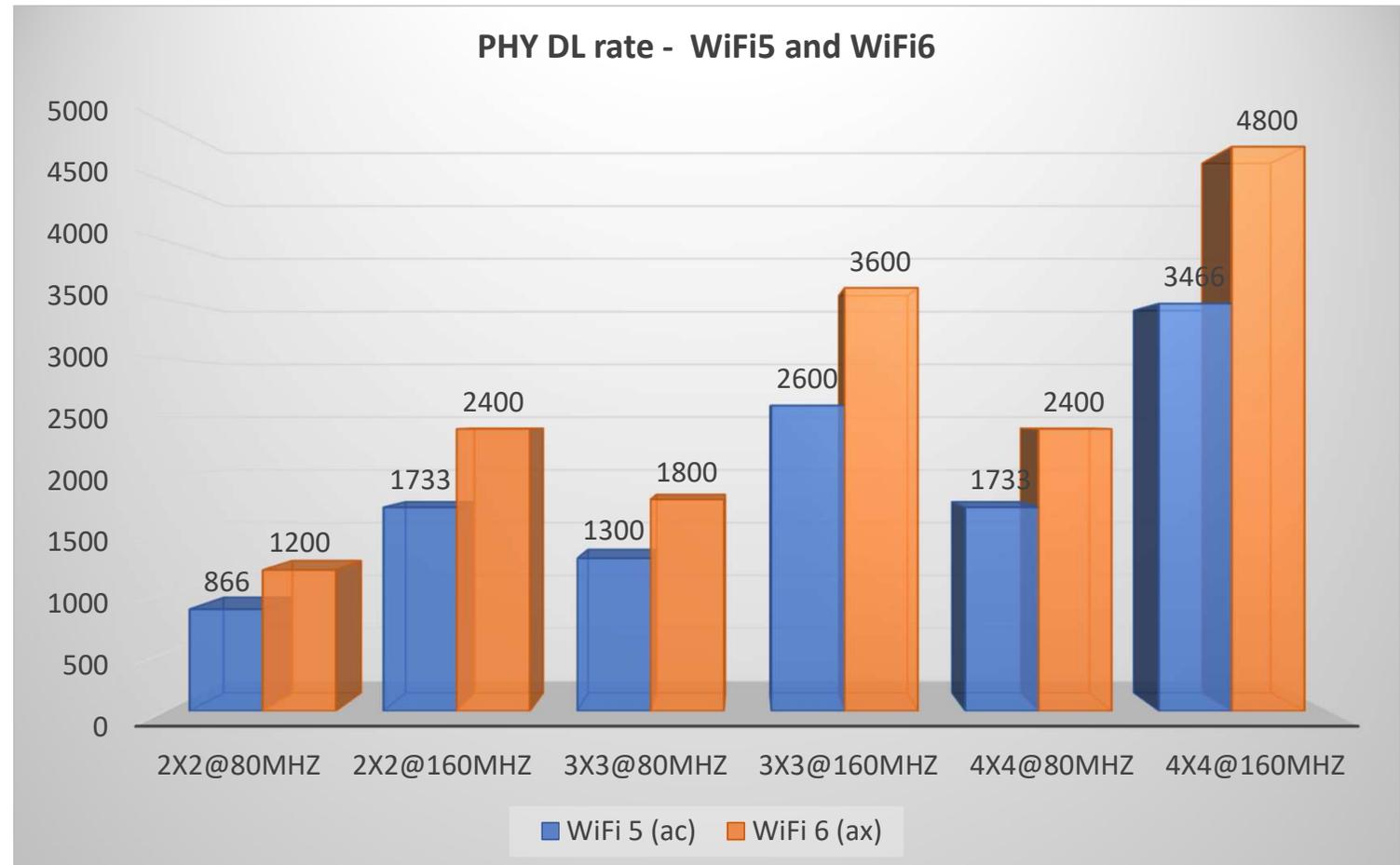
DEPENDENCIES

- **MCS INDEX**
 - NUMBER OF ANTENNAS
 - BANDWIDTH
 - MODULATION/ CODING (MCS)
 - NO. OF SPATIAL STREAM
- ENVIRONMENT (NOISE, CLIENTS)

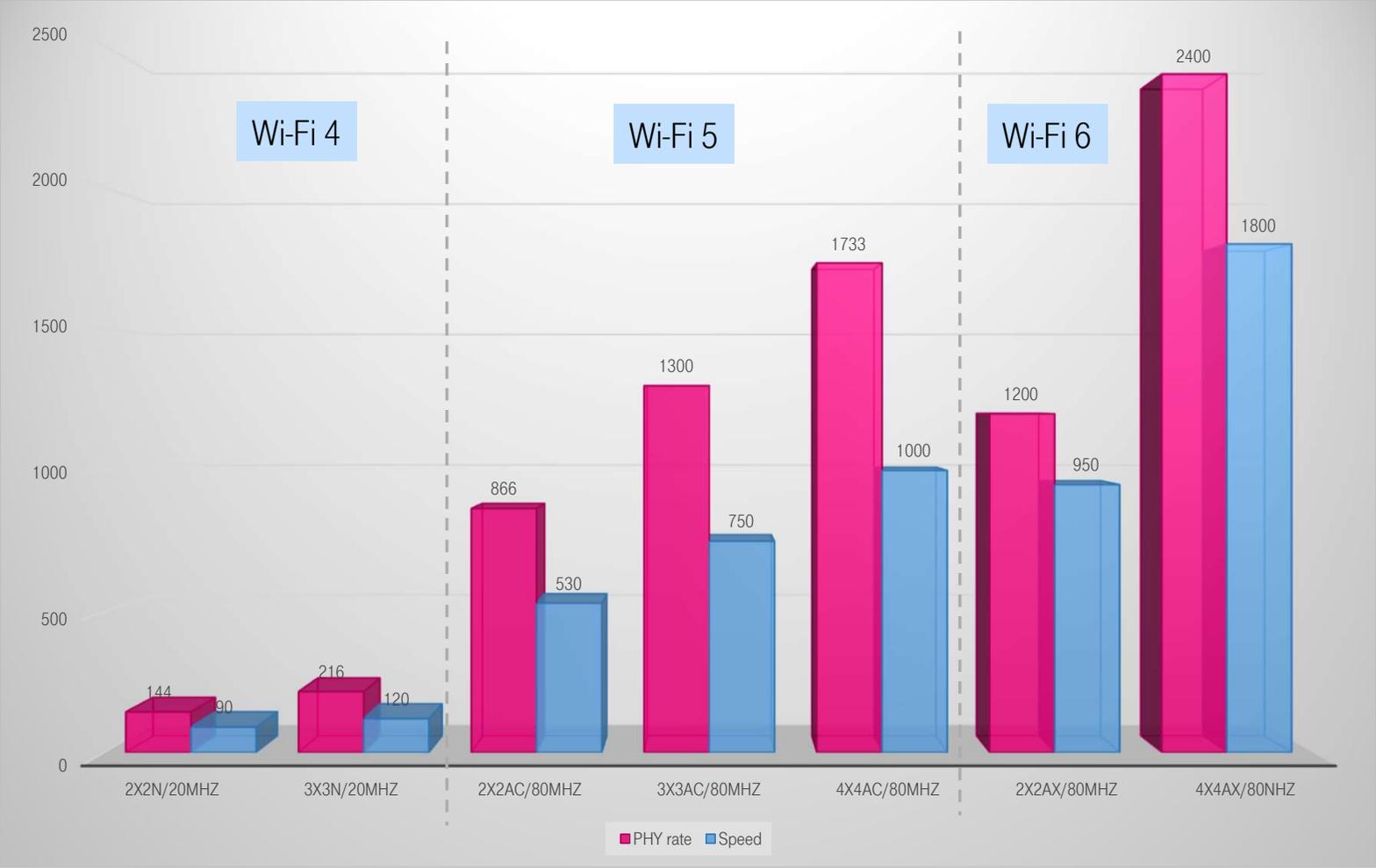
Max Phy rate

WiFi5: 6.9Gbps (160MHz, 8SS, 256QAM)

WiFi6: 9.6Gbps (160MHz, 8SS, 1024 QAM)



TYPICAL PERFORMANCE VALUE OF WI-FI 4, WI-FI 5 & WI-FI 6

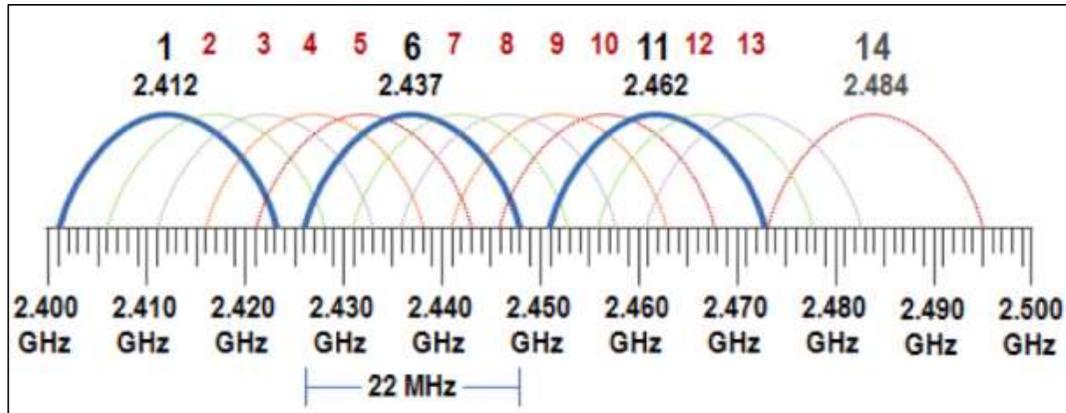




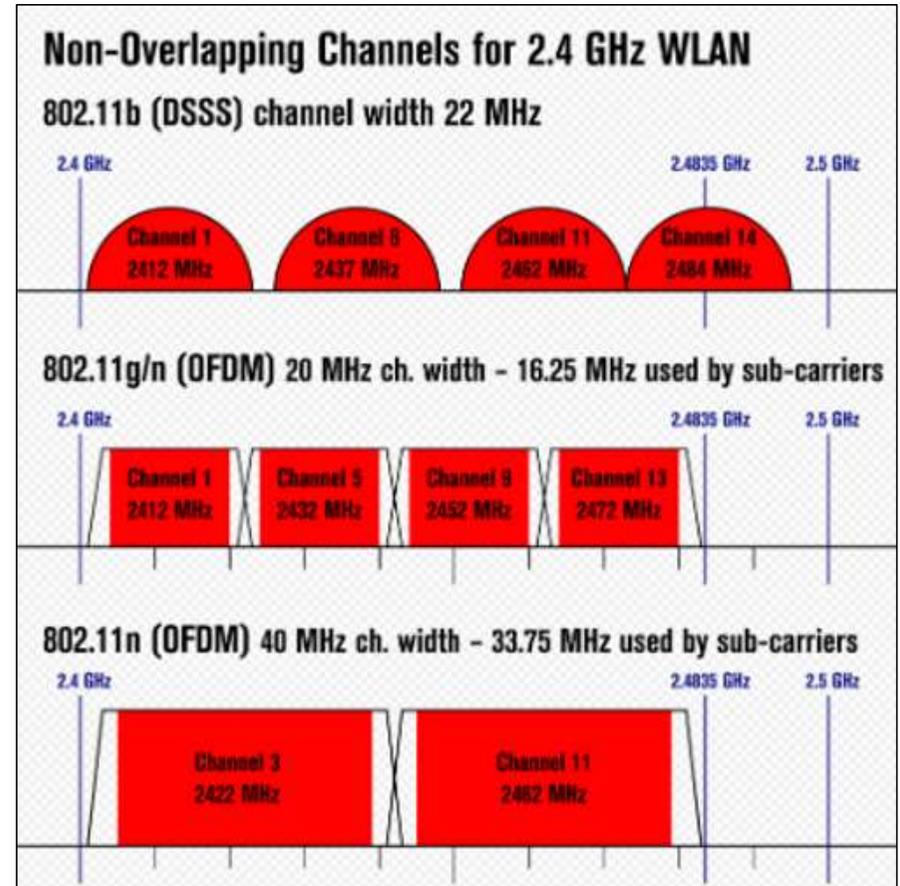
SPECTRUM

WI-FI 6E

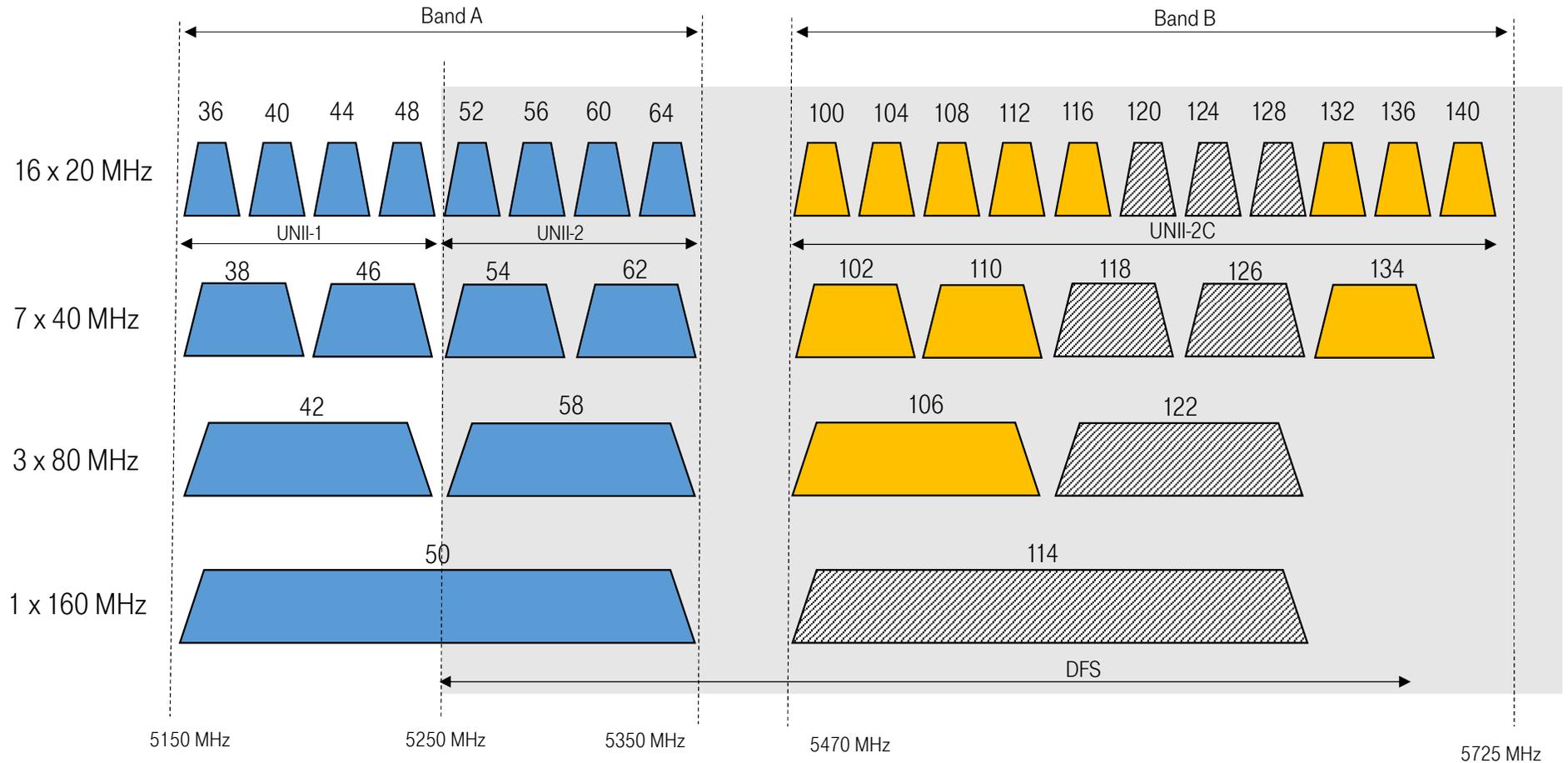
2.4 GHZ SPECTRUM



US: 1-11 channels
EU: 1-13 channels
Japan: 1-14 channels



5 GHZ SPECTRUM – EU (HUNGARY)



DFS: Dynamic Frequency Selection

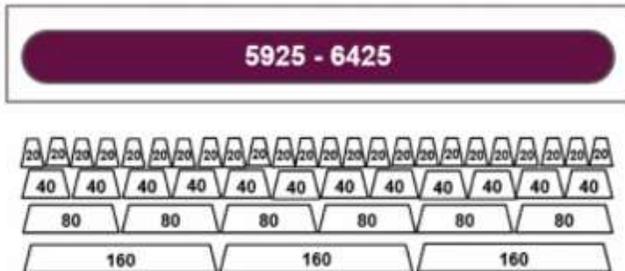
36-64 channels - indoor (200mW)

100-140 channels - indoor/outdoor (1000mW, TPC (Transmission Power Control))

6 GHZ SPECTRUM FOR WI-FI 6E & WI-FI7 FROM 2021



24 x 20 MHz
12 x 40 MHz
6 x 80 MHz
3 x 160 MHz

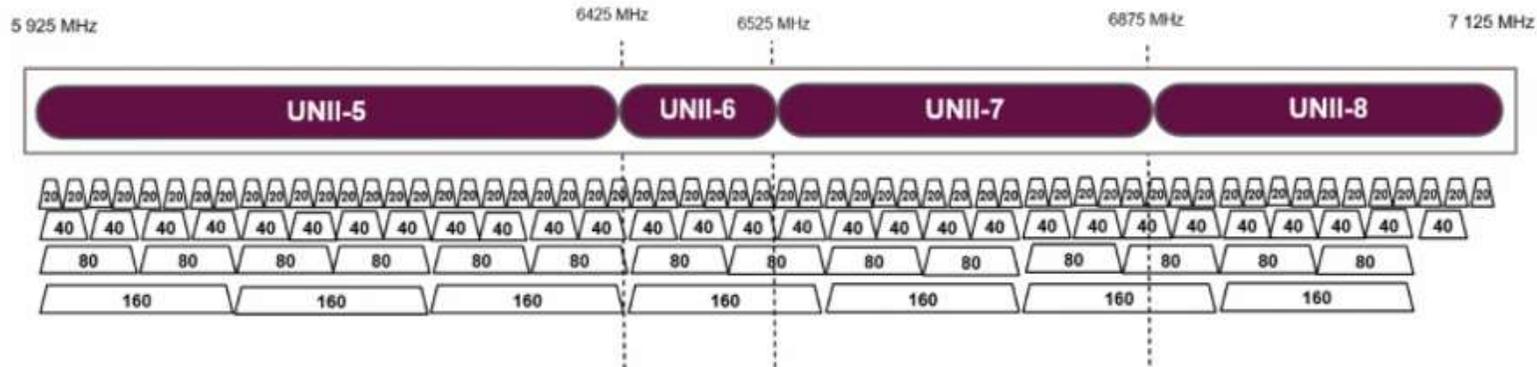


- Dynamic random spectrum access and contention-based protocols require access to **multiple channels** to maintain acceptable performance
- **IEEE 802.11be** designed for Extremely High Throughput -- channel bandwidth of up to **320 MHz**



Other countries

59 x 20 MHz
29 x 40 MHz
14 x 80 MHz
7 x 160 MHz



+500MHz in Europe
+1.2GHz in US



WI-FI & 5G

BOTH WI-FI6 AND 5G ARE BUILT FROM THE SAME FOUNDATION

High Throughput

- WiFi6: 10Gbit/s
- 5G: 10Gbit/s

High Capacity

- WiFi6: 40-100 device / AP
- 5G: 1 million device @1 km²

Low Latency

- WiFi6: <5 ms
- 5G: ~ 1 ms (target value)

| Feature | 5G | Wi-Fi 6 |
|-----------|----------|------------|
| DS | ● | ● |
| US | ● | ● |
| Latency | ● | ● |
| Frequency | licensed | unlicensed |
| Area | outdoor | indoor |

WI-FI6 AND 5G COMPLEMENT EACH OTHER



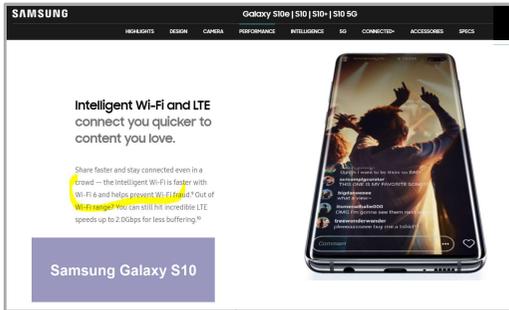
Source: Intel



MARKET OVERVIEW

ALL AROUND WI-FI 6

Samsung Galaxy S10 (Wi-Fi6)



2019 Sept

Routers (Wi-Fi6)



Samsung Galaxy S21 Ultra (Wi-Fi6e)

Samsung Galaxy S21 Ultra 5G

- Released 2021, January 29
- 227g (Sub6), 229g (mmWave), 8.9mm thickness
- Android 11, One UI 3.1
- 128GB/256GB/512GB storage, no card slot

| | | |
|--------------|------------------|--|
| COMMS | WLAN | Wi-Fi 802.11 a/b/g/n/ac/6e, dual-band, Wi-Fi Direct, hotspot |
| | Bluetooth | 5.2, A2DP, LE |
| | GPS | Yes, with A-GPS, GLONASS, BDS, GALILEO |
| | NFC | Yes |
| | Radio | FM radio (Snapdragon model only; market/operator dependent) |
| | USB | USB Type-C 3.2, USB On-The-Go |

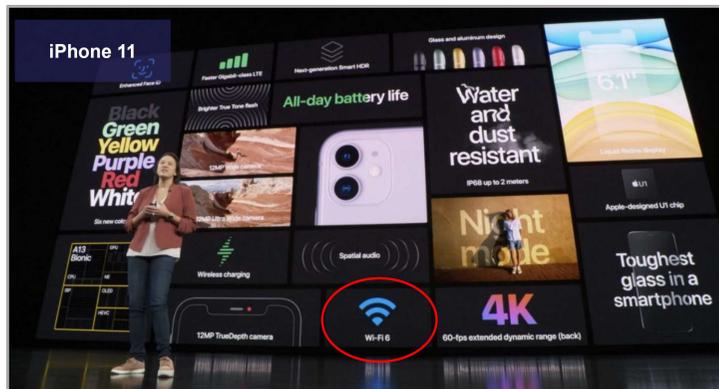
2020.Sept.

2020.Nov

2021 Febr.

2019 March

Iphone 11 (ax)



2x2ax, 80MHz

2021 Jan.



Sagemcom 5670 (GPON/Wi-Fi6)



KAON AR1344 (Wi-Fi6 / MESH)



Xiaomi AX60000 (Wi-Fi6e)

4x4, 160MHz

MARKET TREND: WI-FI6 ECOSYSTEM IS AN INDUSTRY GAME CHANGER

802.11ax Growing Exponentially with End-Devices



Source: WI-FI NOW

The background features a complex, glowing network of interconnected nodes and lines, primarily in shades of blue and orange. The nodes are small, bright points of light, and the lines are thin, glowing filaments that form a mesh-like structure. The overall effect is that of a digital or molecular network, possibly representing a data network or a complex system. The colors transition from a deep blue on the right to a bright orange on the left, creating a sense of depth and energy.

SUMMARY

WIFI 6 PROVIDES HIGHER SPEED AND RELIABLE CONNECTION IN DENSE AREA

1

Increased capacity & data rates

- 25 % increase in capacity thx to 1024QAM
- 40% higher speed
- 75% lower latency under the same condition thx to OFDMA

2

Simultaneous Multi-User support

- MU-MIMO technology & OFDMA help reduce congestion by allowing more device to connect

3

Improved Power Efficiency

- Target Wake Time (TWT) feature allows devices to plan communications with an AP in advance, which helps improve battery life and reduce congestion

4

Performance in hyper-dense environments

- Multiple Access Point deployed in dense device environments deliver the desired QoS to STA with diverse usage profile

The background features a complex, glowing grid of blue lines forming irregular polygons, set against a dark blue and black space. Interspersed within the grid are bright orange and yellow spots, resembling stars or data points. A prominent, bright blue light source is positioned in the upper right, casting a lens flare and illuminating the surrounding grid.

BACKUP

WHAT IS WI-FI? WHAT IS WI-FI6?

- Stands for „Wireless LAN are specified by 802.11 working group of the IEEE 802 LAN/MAN Standards Committee.
- Wireless LAN standards: IEEE 802.11 b/a/g/n/ac/ax/....
- The Wi-Fi Alliance is a consortium of hardware manufacturers that holds the „Wi-Fi” and „Wi-Fi-CERTIFIED” trademarks and certifies WLAN hardware.

| Wi-Fi Alliance Marketing Name | IEEE Standard Name | Release date |
|---|--------------------|----------------|
| Wi-Fi 6  | IEEE 802.11 ax | 2019/2020(jan) |
| Wi-Fi 5  | IEEE 802.11 ac | 2013 (wave2) |
| Wi-Fi 4  | IEEE 802.11 n | 2009 |
| Wi-Fi 3 | IEEE 802.11 g | 2003 |
| Wi-Fi 2 | IEEE 802.11 a | 1999 |
| Wi-Fi 1 | IEEE 802.11 b | 1999 |

