



# Wi-Fi 6/6E

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# Outline

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- Introduction
- Wi-Fi SPEC
- Technology Analysis
- Industry Analysis
- Conclusion
- Reference

# Introduction



## ■ History

Wi-Fi generations

Generation	IEEE standard	Maximum throughput	Adopted	Radio frequency GHZ
Wi-Fi "0"*	802.11	2Mbit/s	1997	2.4
Wi-Fi "1"*	802.11b	11Mbit/s	1999	2.4
Wi-Fi "2"*	802.11a	54Mbit/s	1999	5
Wi-Fi "3"*	802.11g	54Mbit/s	2003	2.4
Wi-Fi 4	802.11n	600Mbit/s	2008	2.4/5
Wi-Fi 5	802.11ac	6.8Gbit/s	2014	5
Wi-Fi 6	802.11ax	10Gbit/s	2019	2.4/5
Wi-Fi 6E	802.11ax	10Gbit/s	2020	6
Wi-Fi 7	802.11be	46Gbit/s	2024	1–7.25 (2.4/5/6)

\*non-official designation



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# Wi-Fi SPEC

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## ■ Wi-Fi comparison

	Wi-Fi 5	Wi-Fi 6	Wi-Fi 6E
Operating bands	5 GHz	2.4 GHz, 5 GHz	6 GHz
Modulation scheme	OFDM	OFDMA	OFDMA
Channel width	20 MHz, 40 MHz, 80 MHz, 160 MHz	20 MHz, 40 MHz, 80 MHz, 160 MHz	20 MHz, 40 MHz, 80 MHz, 160 MHz
Highest modulation	256-QAM	1024-QAM	1024-QAM
MIMO streams	Up to 8x8	Up to 8x8	Up to 8x8
MU-MIMO	Downlink MU-MIMO	Downlink and Uplink-MU-MIMO	Downlink and Uplink-MU-MIMO
Target Wake Time (TWT)	No	Yes	Yes
BSS Coloring	No	Yes	Yes
Extended Range Improvements	No	Yes	Yes



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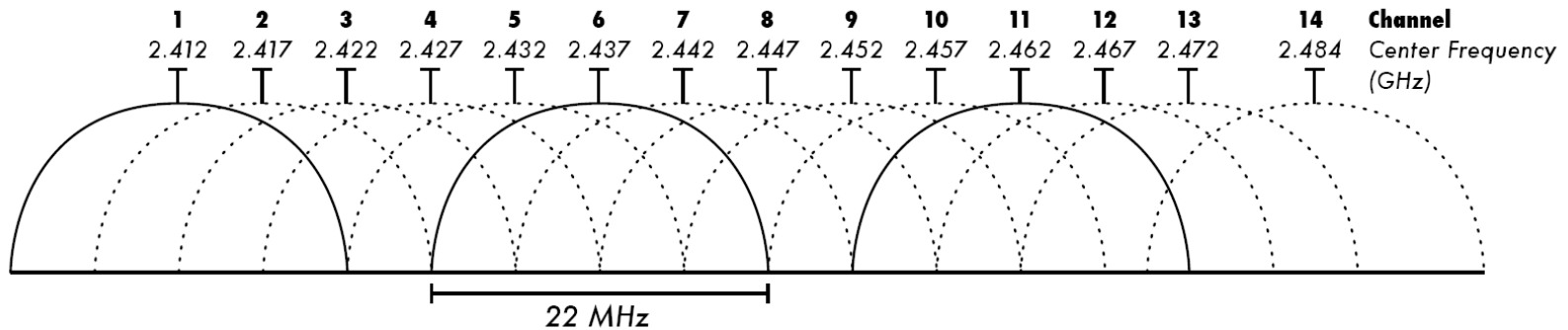
# Technology Analysis

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- **Frequency Band: 2.4 GHz, 5 GHz and 6 GHz(Wi-Fi 6E)**
- **Modulation: 1024-QAM**
- **Modulation scheme: OFDMA**
- **MU-MIMO**
- **Basic Service Set (BSS) Coloring**
- **Target Wake Time (TWT) – Battery life**
- **Security: WPA3**

# Frequency Band

## ■ 2.4 GHz



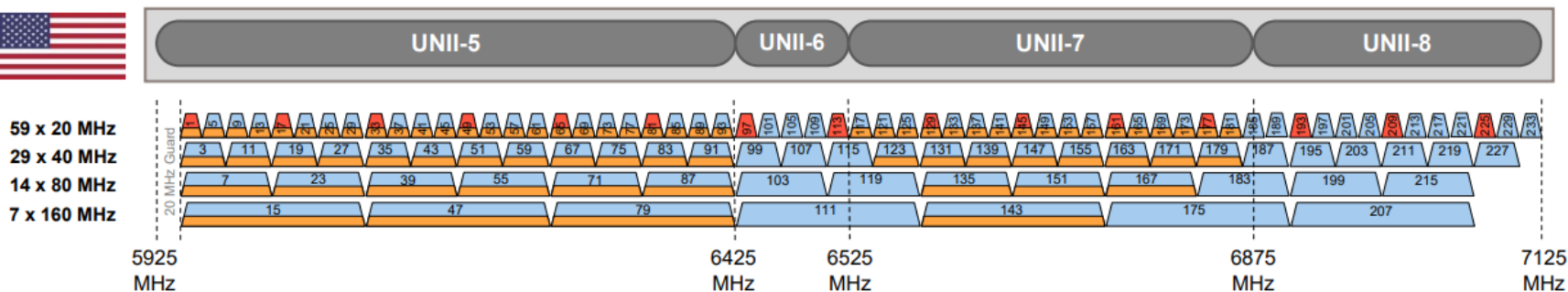
## ■ 5 GHz (DFS, Dynamic Frequency Selection)

Frequency (GHz)	5.150	5.250	5.470	5.600	5.640	5.725	5.850
		DFS Channels					
				TDWR			
802.11 Allocations	UNII-1	UNII-2a	UNII-2c (Extended)			UNII-3	
20 MHz	36 40 44 48	52 56 60 64	100 104 108 112 116 120 124 128	132 136 140 144	149 153 157 161 165		
40 MHz	38 46	54 62	102 110 118 126	134 142	151 159		
80 MHz	42	58	106 122	138	155		
160 MHz	50		114				
Rules	1000mW Tx Power Indoor & Outdoor No DFS needed	250mw w/6dBi Indoor & Outdoor DFS Required	250mw w/6dBi Indoor & Outdoor DFS Required 144 Now Allowed	120, 124, 128 Devices Now Allowed		1000mW Tx Power Indoor & Outdoor No DFS needed 165 was ISM, now UNII-3	



# Frequency Band

## 6 GHz Channels in United States & Europe/CEPT



# Frequency Band

Band	Channels	BW
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**2.4 GHz**

3  
1

20 MHz  
40 MHz

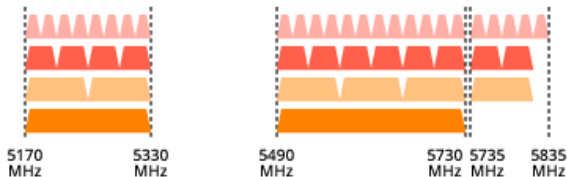


**60 MHz of Spectrum  
3 Channels Allocated**

**5 GHz**

25  
12  
6  
2

20 MHz  
40 MHz  
80 MHz  
160 MHz

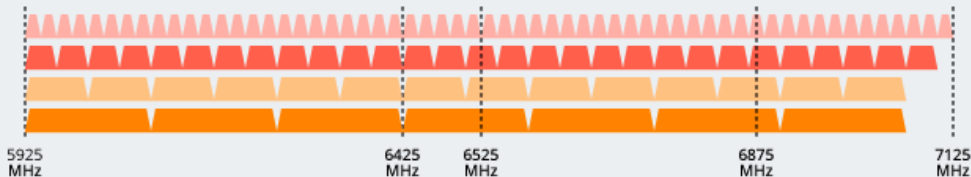


**500 MHz of Spectrum  
25 Channels Allocated**

**6 GHz**

59  
29  
14  
7

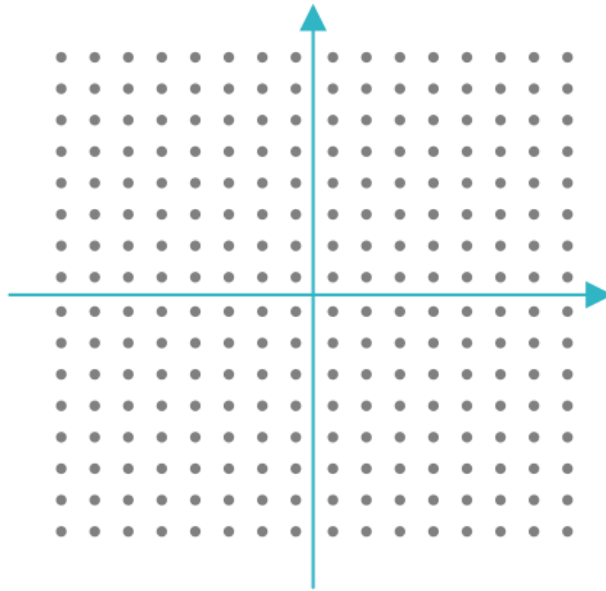
20 MHz  
40 MHz  
80 MHz  
160 MHz



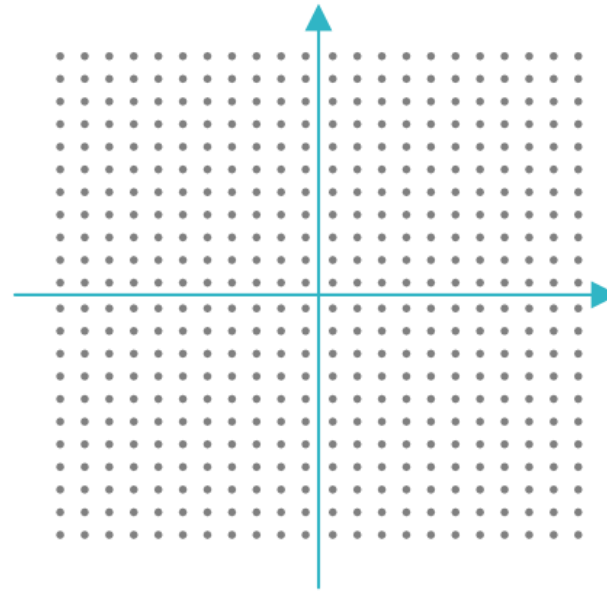
Up to  
**1,200 MHz of New Spectrum**  
**56 Channels Available**  
including up to seven 160 MHz Channels

# Modulation

## ■ 256-QAM vs. 1024-QAM



Wi-Fi 5  
256-QAM

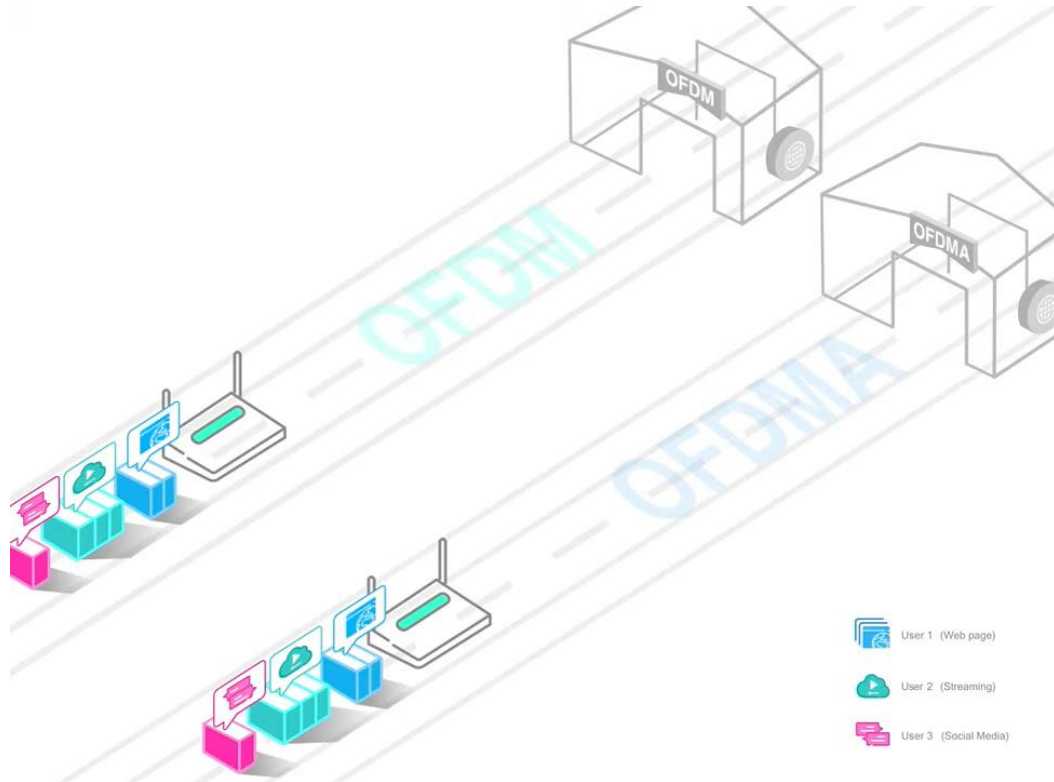


Wi-Fi 6  
1024-QAM

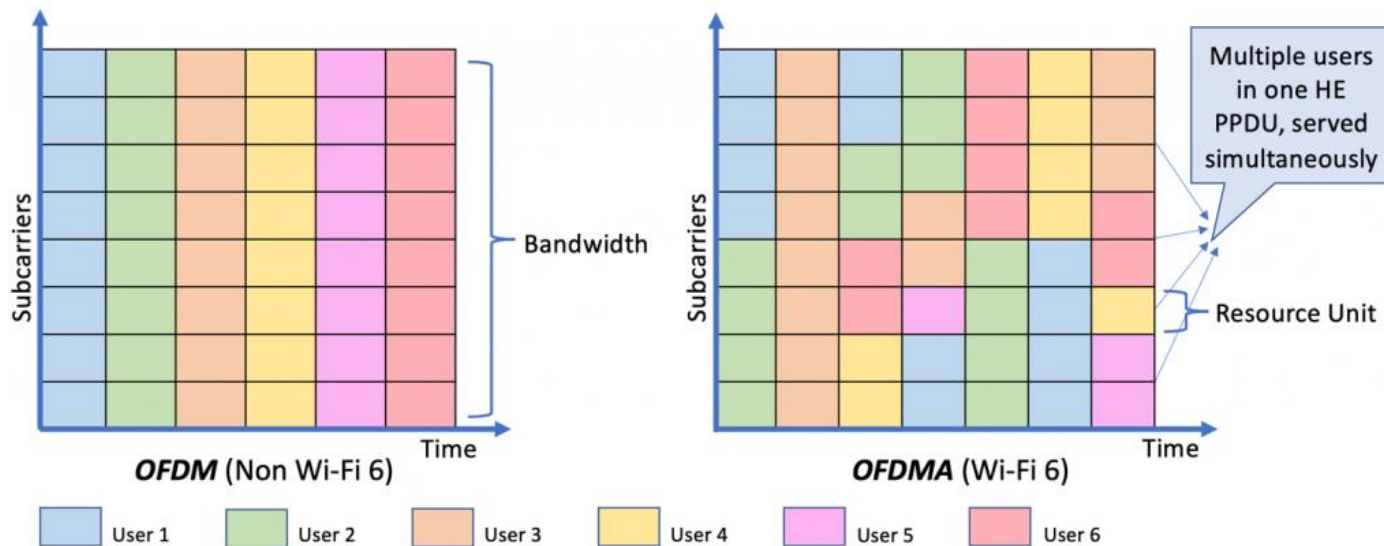
- Bits per symbol: From 8 bit to 10 bit
- Increasing the data throughput of a single spatial stream by 25%

# Modulation scheme

## ■ OFDM vs. OFDMA

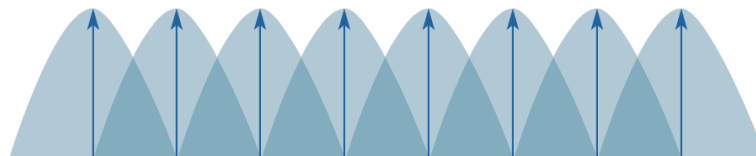


# OFDMA



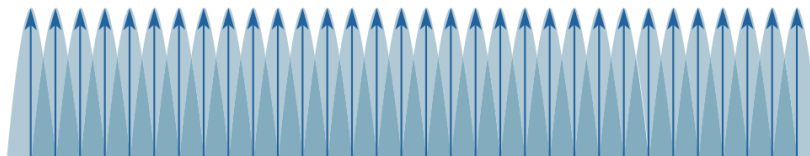
## ■ Subcarrier Size

802.11a/g/n/ac subcarriers



312.5 kHz

802.11ax subcarriers

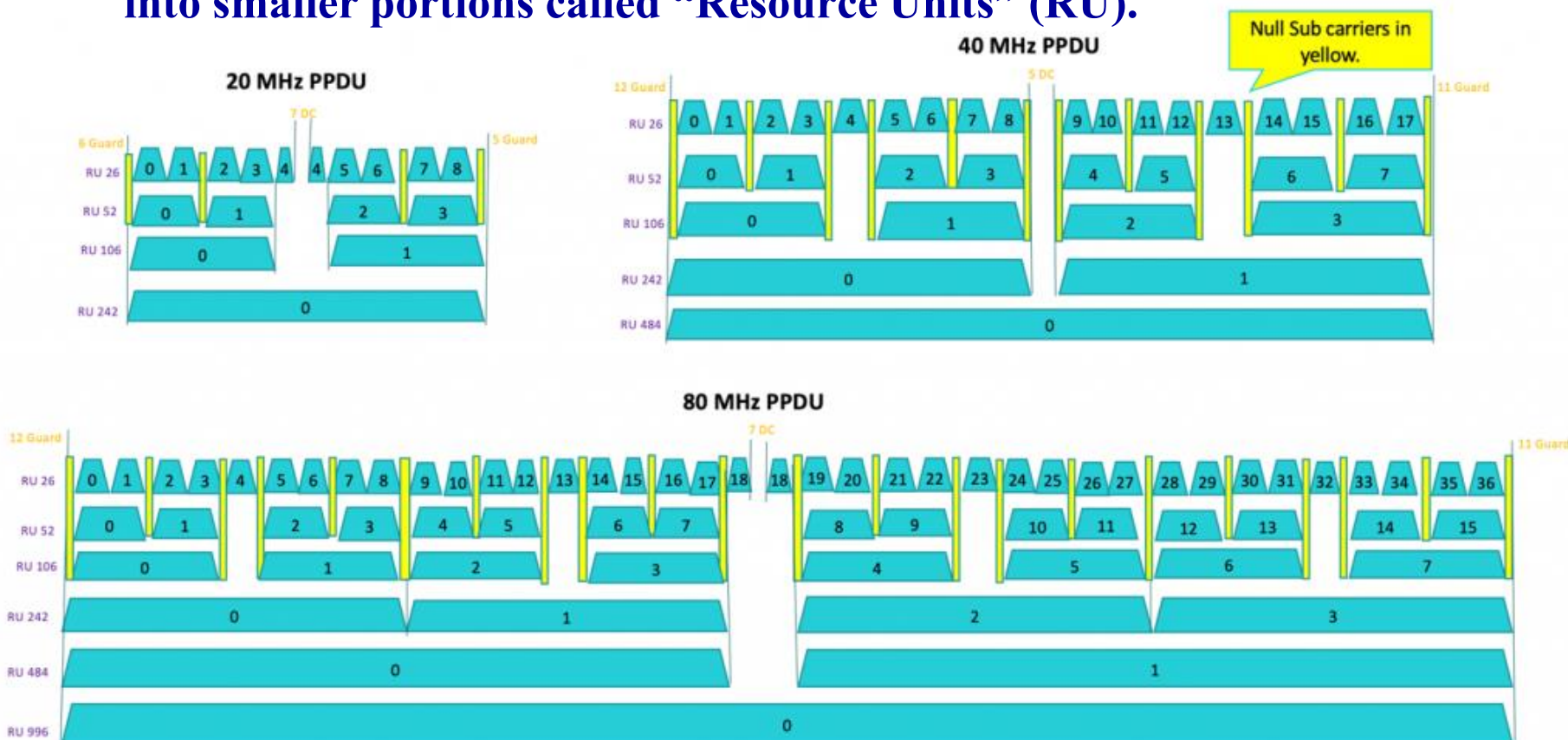


78.125 kHz

# OFDMA

RU type	20 MHz BW	40 MHz BW	80 MHz BW	80+80/160 MHz BW
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
484-tone RU	N/A	1	2	4
996-tone RU	N/A	N/A	1	2
2x996-tone RU	N/A	N/A	N/A	1

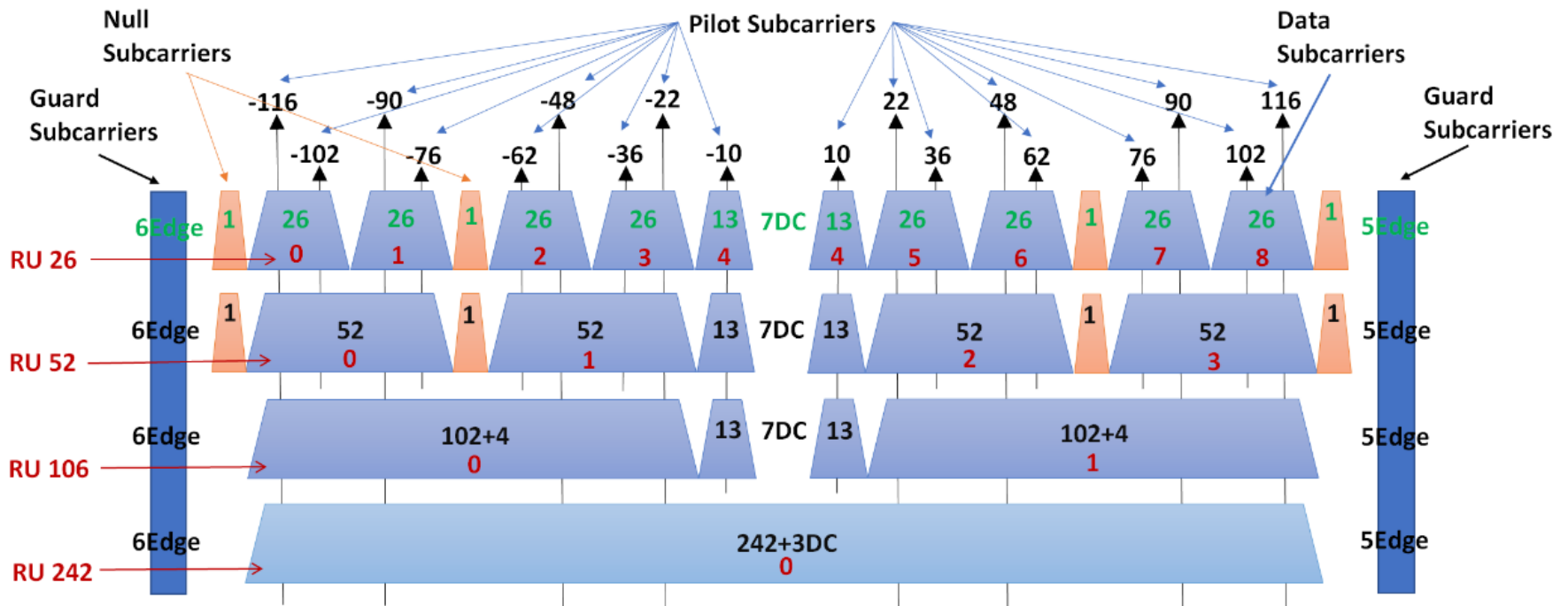
- OFDMA allows subcarriers in a channel bandwidth to be grouped into smaller portions called “Resource Units” (RU).



# OFDMA

■ For example:

$$6\text{edge} + 1 + 26 + 26 + 1 + 26 + 26 + 13 + 7\text{DC} + 13 + 26 + 26 + 1 + 26 + 26 + 1 + 5\text{edge} = 256$$

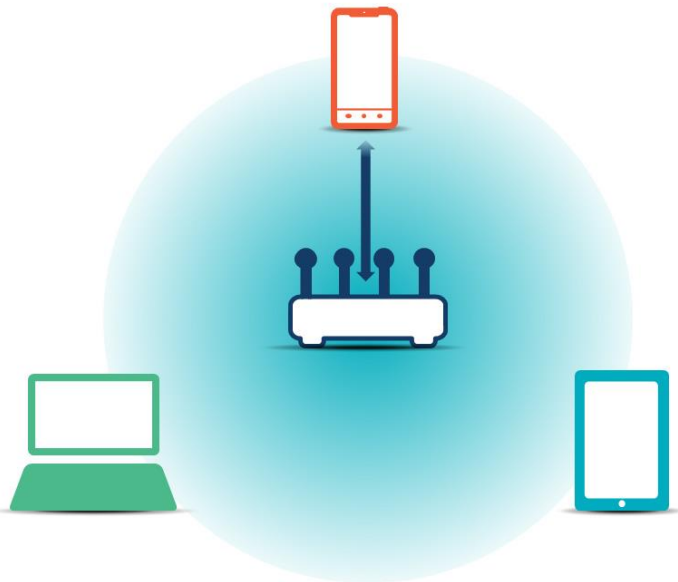




# MU-MIMO

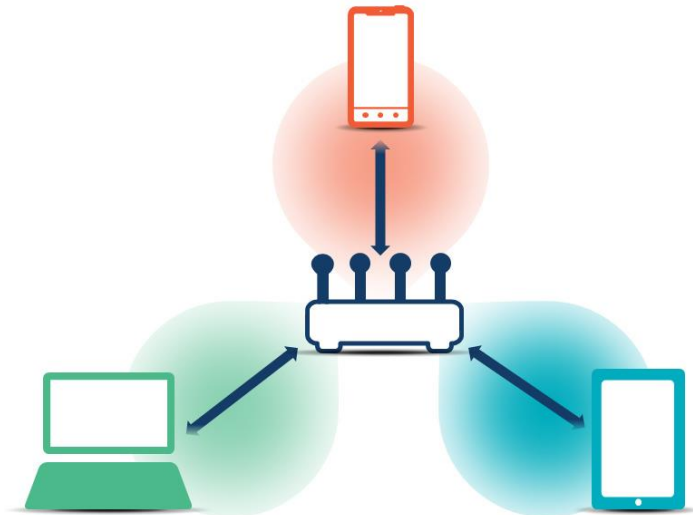
## Single-User MIMO

Serves one device at a time



## Multi-User MIMO

Multi-user beamforming (MUBF) serves multiple devices simultaneously





# OFDMA vs. MU-MIMO

## OFDMA and MU-MIMO



### OFDMA

- OFDMA increases efficiency
- OFDMA reduces latency
- Ideal for low-bandwidth applications



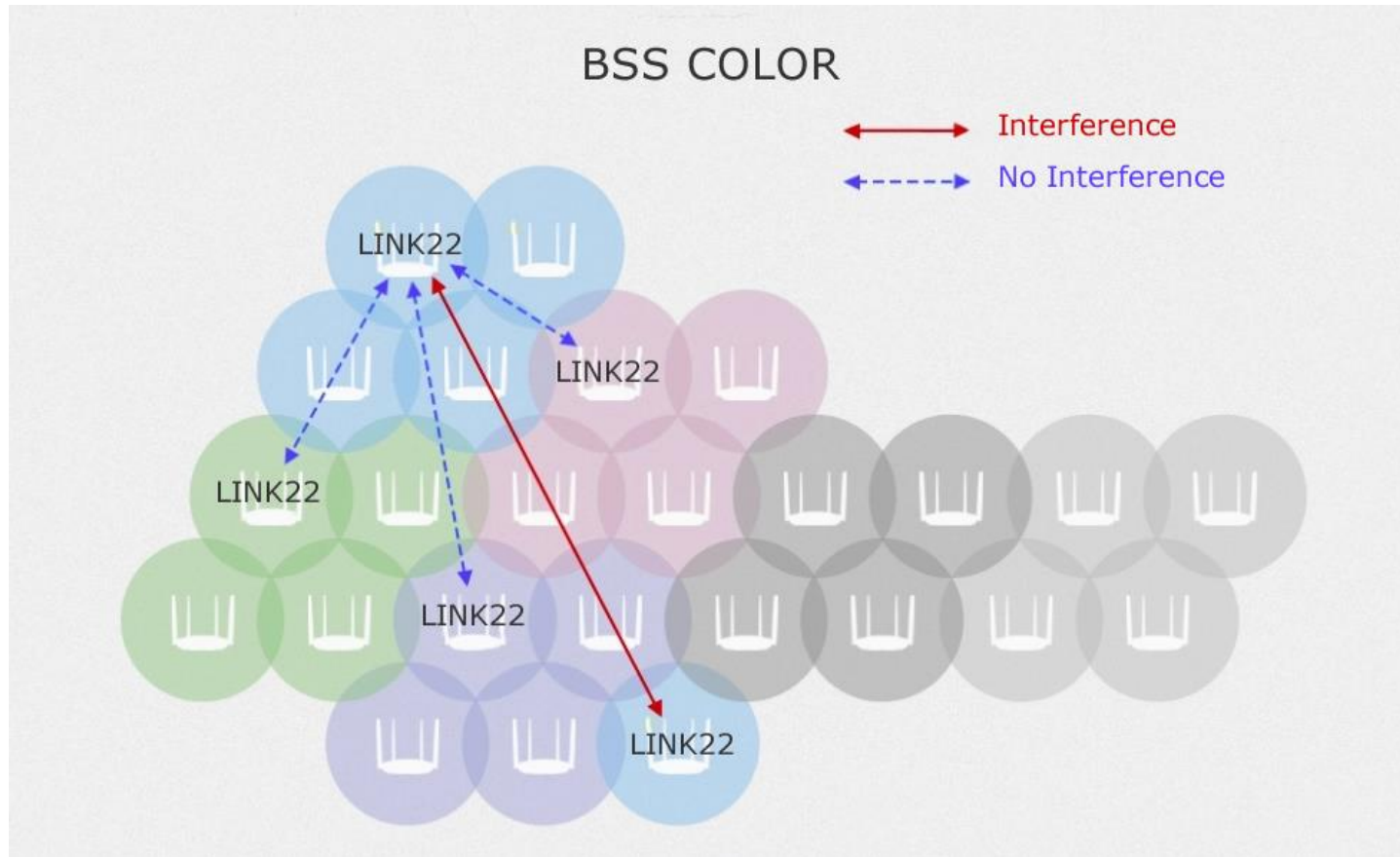
### MU-MIMO

- MU-MIMO increases capacity
- MU-MIMO results in higher speeds per user
- Ideal for high-bandwidth applications

MU-MIMO is similar to multiple trucks serving users simultaneously

# Basic Service Set (BSS) Coloring

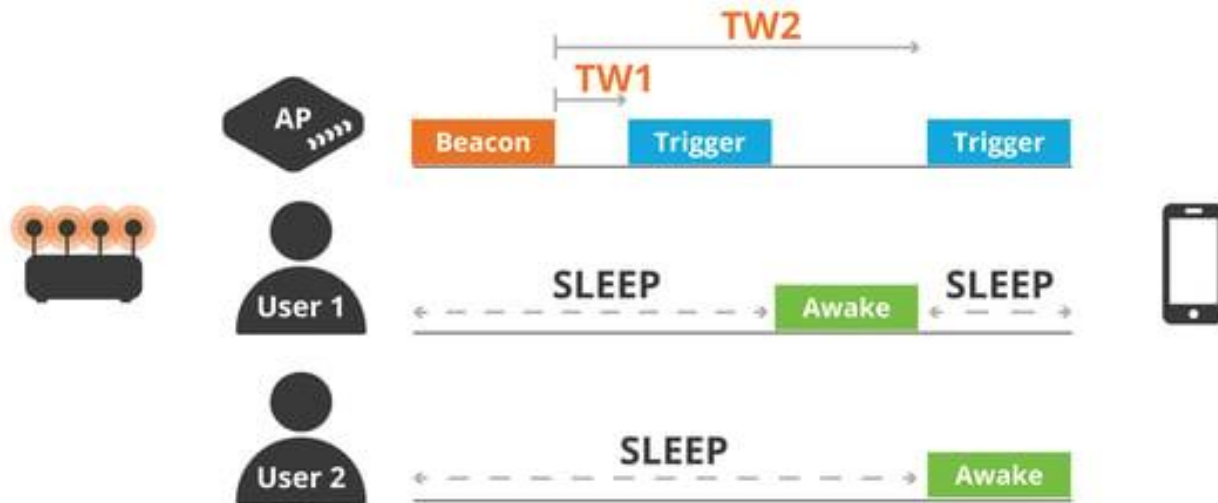
## ■ Basic Service Set (BSS) Coloring



# Target Wake Time (TWT)

## RESOURCE SCHEDULING SIGNIFICANTLY IMPROVES DEVICE BATTERY LIFE

TWT : Target Wake Time



- AP and devices negotiate and define a specific times to access the medium
- Reduced contention and overlap between users
- Significantly increases the device sleep time to reduce power consumption



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# Industry Analysis

## ■ Smartphones with Wi-Fi 6 (2019) Compatibility

	Smartphones	Date
Samsung Galaxy	S10, S10+, S10e	March 2019
iPhone	11 Series	September 2019
Xiaomi	Mi 10 5G, Mi 10 Pro 5G	February 2020
Vivo	iQOO 3 5G	February 2020
Sony Xperia	1 II	February 2020
Realme	X50 Pro 5G	February 2020
LG	V60 ThinQ 5G	March 2020
OnePlus	8, 8 Pro	April 2020
Motorola	Edge Plus	May 2020
ASUS	ROG Phone 3, Phone 3 Strix	July 2020
Google	Pixel 6 and 6 Pro	October 2021



# Wi-Fi 6 Router SPEC

## ■ IPQ8071

### Specifications

<b>Chipset</b>	CPU: Qualcomm IPQ8071 (optional IPQ8072/IPQ8070)
	2.4 AX Chip: Qualcomm 2X2; SINGLE-BAND; 802.11AX QCN5024
	5GHZ AX Chip: Qualcomm 4X4; SINGLE-BAND; 802.11AX QCN5054
	Ethernet 5 Giga port switch: Qualcomm QCA8075
	Power management: PMP8074
<b>System Memory</b>	Default DDR3-2400 512Mbyte
<b>NAND Flash</b>	Default 256Mbyte
<b>M2 LTE Module</b>	1x 3G/4G/5G M.2 Module with SIM card
<b>Interface</b>	1* WAN 1000M with POE PD 25W Support (802.3at & af standard)
	3* LAN Giga Ethernet RJ45 Port
	1x SIM Card Slot
<b>Reset Button</b>	Yes
<b>DC Power</b>	1x DC Jack Connector: 12V@2A
<b>Power Consumption</b>	20 Watt (Max)
<b>Software</b>	OpenWRT or Qualcomm QSDK which includes Uboot, Kernel and Tool Chain
<b>Environmental</b>	Temperature: Operating: -20°C to 85°C, Storage: -40°C to 90°C
	Humidity (non-condensing): Operating: 5% to 95%, Storage: Max. 90%
<b>PCBA</b>	Dimensions: 155 x 120 x 16 mm

# Wi-Fi 6 Router

- IPQ8071 WIFI 11AX PHY rate: 2402 Mbps (5 GHz) and 574 Mbps (2.4 GHz), enabling an AX3000 product.

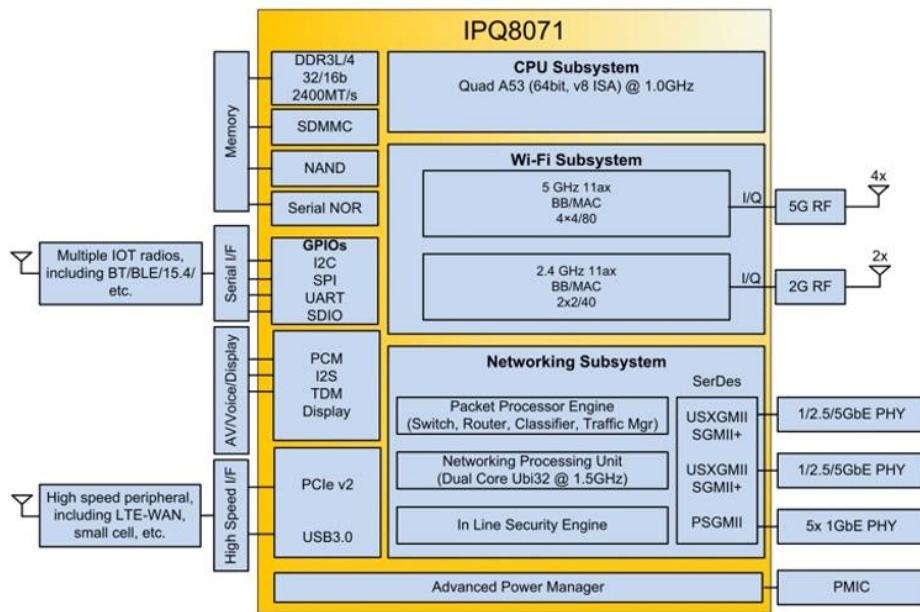
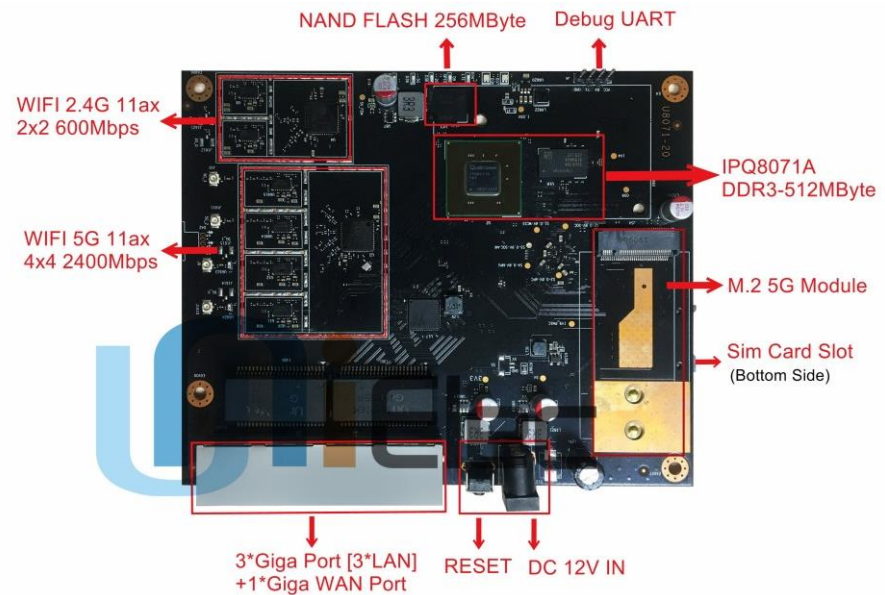


Figure 1-1 IPQ8071 functional block diagram



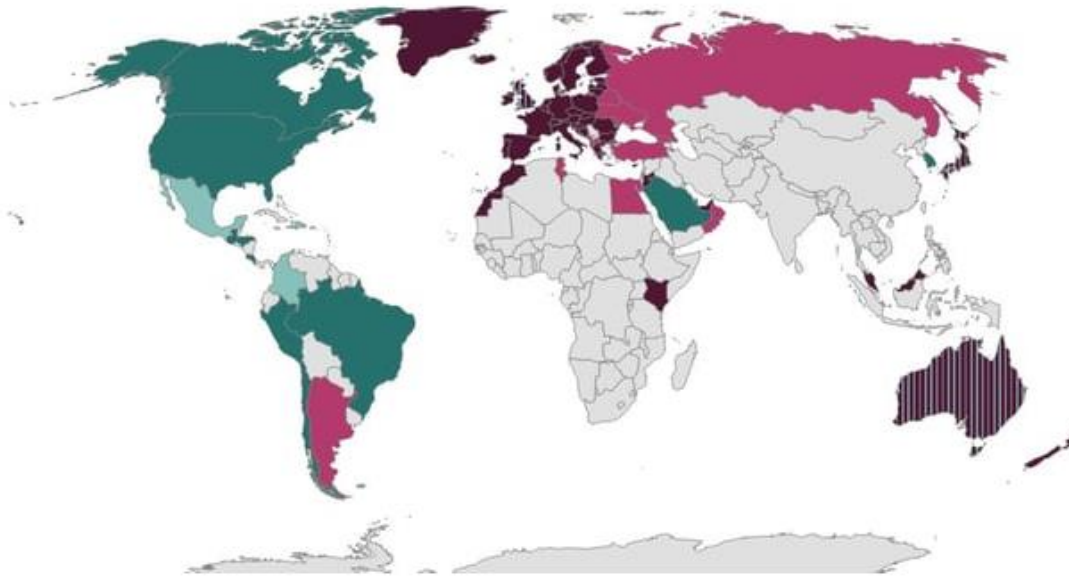
- 5 GHz: SU-MIMO (4ss, 1 user), DL MU-MIMO (4ss, 4 users), DL-OFDMA (8 users)
- 2.4 GHz: SU-MIMO (2ss, 1 user), DL MU-MIMO (2ss, 2 users), DL-OFDMA (8 users)



# Wi-Fi 6E

Curious as to what countries have actually adopted the new Wi-Fi 6E / 6 GHz frequency spectrum?

- Adopted 5925-6425 MHz
- Adopted 5925-7125 MHz
- Considering 5925-6425 MHz
- Considering 5925-7125 MHz
- Adopted 5925-6425 MHz, Considering 6425-7125 MHz



Source: Wi-Fi Alliance | Nations Adopting Wi-Fi 6E / 6 GHz

■ 2022/08/15





# SWOT

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## STRENGTHS

- Higher Data rate
- Lower Latency
- Energy-Saving
- Enhanced security
- Not crowded – 6 GHz

S

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## WEAKNESSES

For customer

- Higher price
- To Upgrade is complicated Wi-Fi 6E
- 6 GHz band is not allowed in some countries yet

## OPPORTUNITIES

- eSports
- IoT

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## THREATS

- Wi-Fi 7 (2024)



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# Conclusion

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- **Wi-Fi is a mature technology. Its development strategies are clear.**
  - Lower Latency
  - Higher Throughputs
  - Increasing Access Point Capacity
- **Features of Wi-Fi 6/6E**
  - 1024-QAM
  - MU-MIMO
  - OFDMA
  - TWT
  - BSS Coloring
  - WPA3
  - 6GHz (Wi-Fi 6E)
- **Wi-Fi 7 is coming. Users might choose Wi-Fi 7 instead of Wi-Fi 6E.**
  - Wi-Fi 6E acts as a bridge between Wi-Fi 6 and Wi-Fi 7



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