qorvo
all around you

5G vs IEEE 802.11ax (WiFi 6)

第五代行動通訊(5G)與第六代Wi-Fi (Wi-Fi 6)無線網路的正面對決

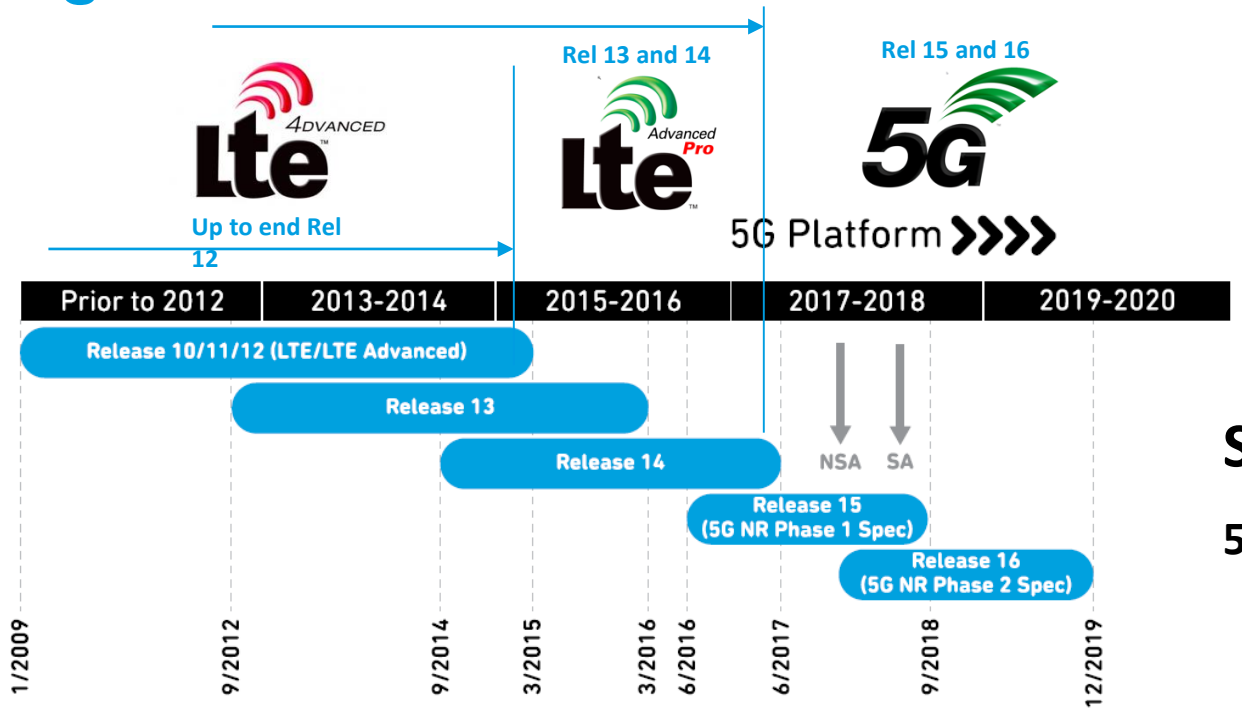
Jeff Lin
Dec 4th, 2018

IEEE 802.11ax

Why we need new technologies?

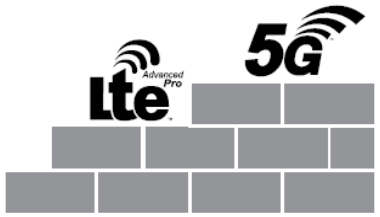
3GPP Timeline

Building 5G on the Foundation of LTE Advance / Advance Pro



NSA: Stage 3 Completion for Non-StandAlone 5G-NR (12/2017)

SA: Stage 3 Completion for StandAlone 5G-NR (6/2018)



Built on the foundation of 4G LTE

Some Important Reality Checks

5G Non-Stand Alone (NSA) Approved by Dec 2017

- **Enables Low Capex early 5G (2019)**
- **Uses a 4G LTE band for the Control Plane Anchor for a 5G New Radio Band**
- **Avoids need to build-out a 5G core network (SA) while testing market use-cases (cheap)**

Multiple NR Bands Designated in 3GPP

Selected Few Targeted for Deployment by 2020

Band number	UL	DL	Duplex mode
n1	1920 – 1980 MHz	2110 – 2170 MHz	FDD
n2	1850 – 1910 MHz	1930 – 1990 MHz	FDD
n3	1710 – 1785 MHz	1805 – 1880 MHz	FDD
n5	824 – 849 MHz	869 – 894 MHz	FDD
n7	2500 – 2570 MHz	2620 – 2690 MHz	FDD
n8	880 – 915 MHz	925 – 960 MHz	FDD
n20	832 – 862 MHz	791 – 821 MHz	FDD
n28	703 – 748 MHz	758 – 803 MHz	FDD
n38	2570 – 2620 MHz	2570 – 2620 MHz	TDD
n41	2496 – 2690 MHz	2496 – 2690 MHz	TDD
n50	1432 – 1517 MHz	1432 – 1517 MHz	TDD
n51	1427 – 1432 MHz	1427 – 1432 MHz	TDD
n66	1710 – 1780 MHz	2110 – 2200 MHz	FDD
n70	1695 – 1710 MHz	1995 – 2020 MHz	FDD
n71	663 – 698 MHz	617 – 652 MHz	FDD
n74	1427 – 1470 MHz	1475 – 1518 MHz	FDD
n75	N/A	1432 – 1517 MHz	SDL
n76	N/A	1427 – 1432 MHz	SDL
n77	3.3 – 4.2 GHz	3.3 – 4.2 GHz	TDD
n78	3.3 – 3.8 GHz	3.3 – 3.8 GHz	TDD
n79	4.4 – 5.0 GHz	4.4 – 5.0 GHz	TDD
n80	1710 – 1785 MHz	N/A	SUL
n81	880 – 915 MHz	N/A	SUL
n82	832 – 862 MHz	N/A	SUL
n83	703 – 748 MHz	N/A	SUL
n84	1920 – 1980 MHz	N/A	SUL

Band number	UL	DL	Duplex mode
n257	26.5 – 29.5 GHz	26.5 – 29.5 GHz	TDD
n258	24.25 – 27.5 GHz	24.25 – 27.5 GHz	TDD
n259	31.8 – 33.4 GHz	31.8 – 33.4 GHz	TDD
n260	37 – 40 GHz	37 – 40 GHz	TDD

Market Update for mmW 5G

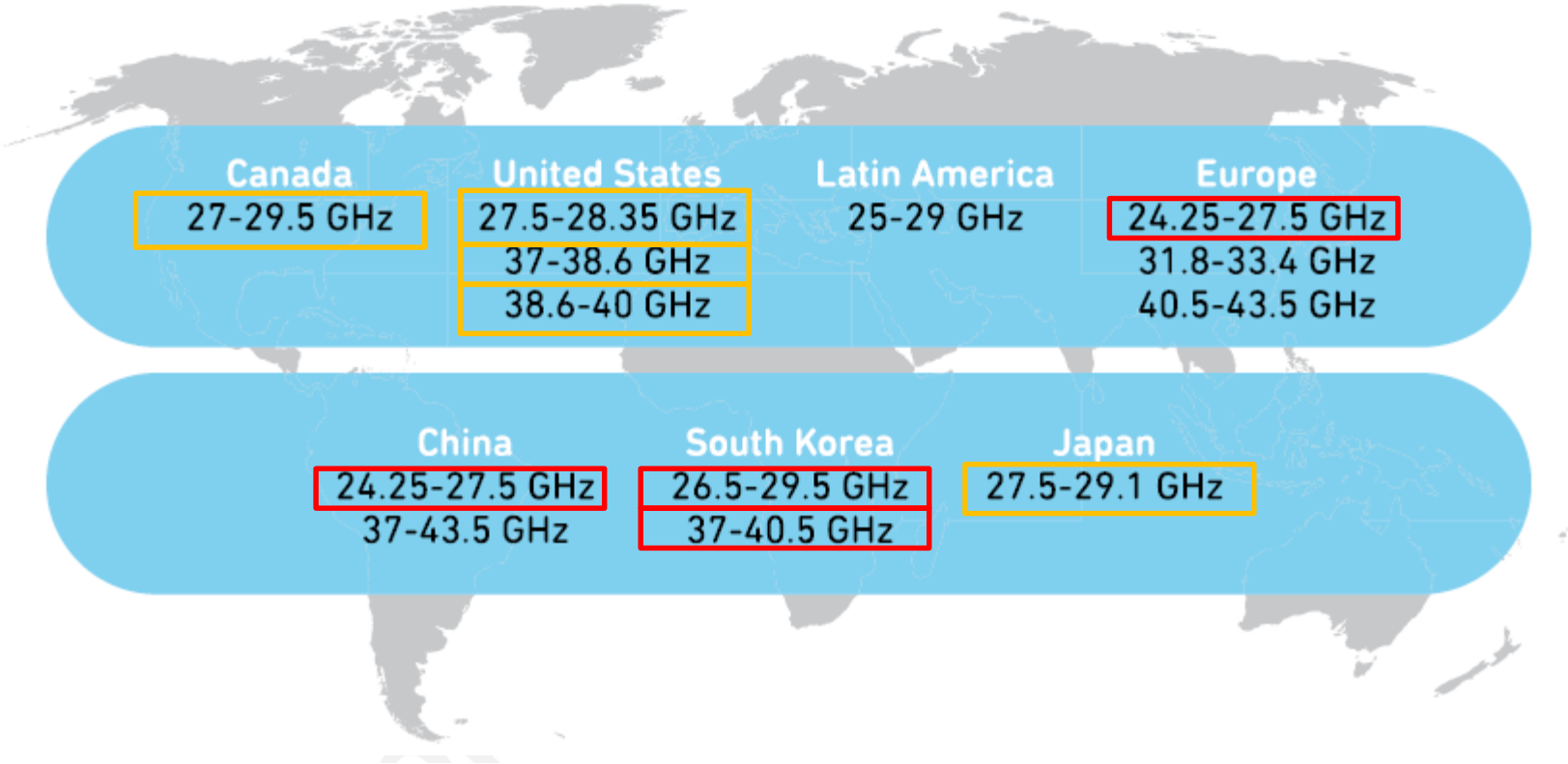
- 3GPP Release 15 NR specification released
  - Nonstandalone (NSA) 5G NR release that does not require a 5G core network, uses LTE to enable large-scale trials and deployments in 2018

- Timing for fixed wireless access is pulling in
  - AT&T: 5G mmW FWA rollout in Dallas, Waco and Atlanta **this year**
  - Verizon: 5G mmW FWA rollout to several cities across U.S **this year**
  - T-Mobile: 5G mmW **mobile** rollout in CY2019

mmW Frequencies

Still Evolving

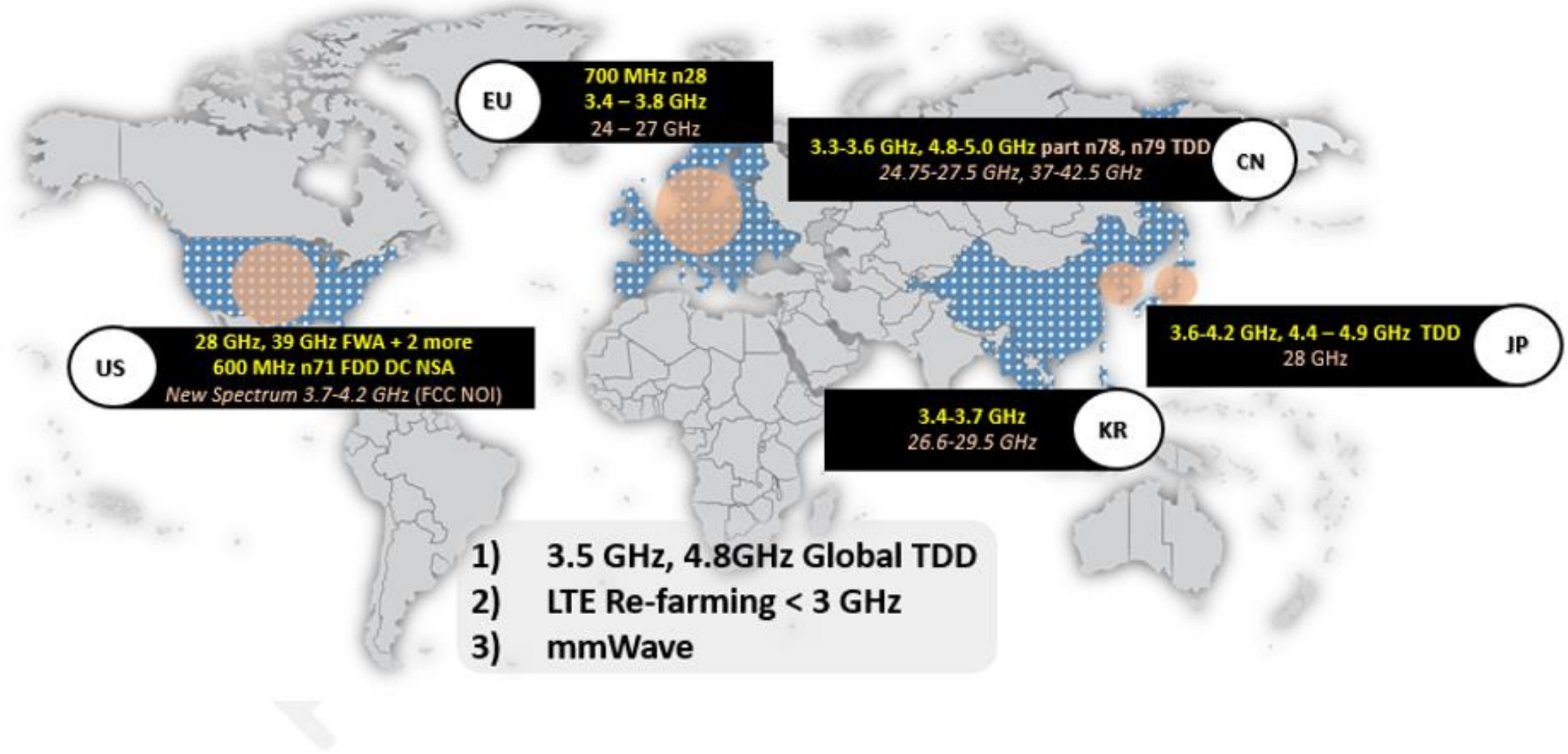
NR mmW bands:
- n257: 26.5-29.5GHz
- n258: 24.25-27.5GHz
- n259: 31.8-33.4GHz
- n260: 37-40GHz



- 26.5-29.5GHz (U.S. and S. Korea) and 37-40GHz (U.S.)
- 24.25-27.5GHz band may possibly follow (Europe/China)

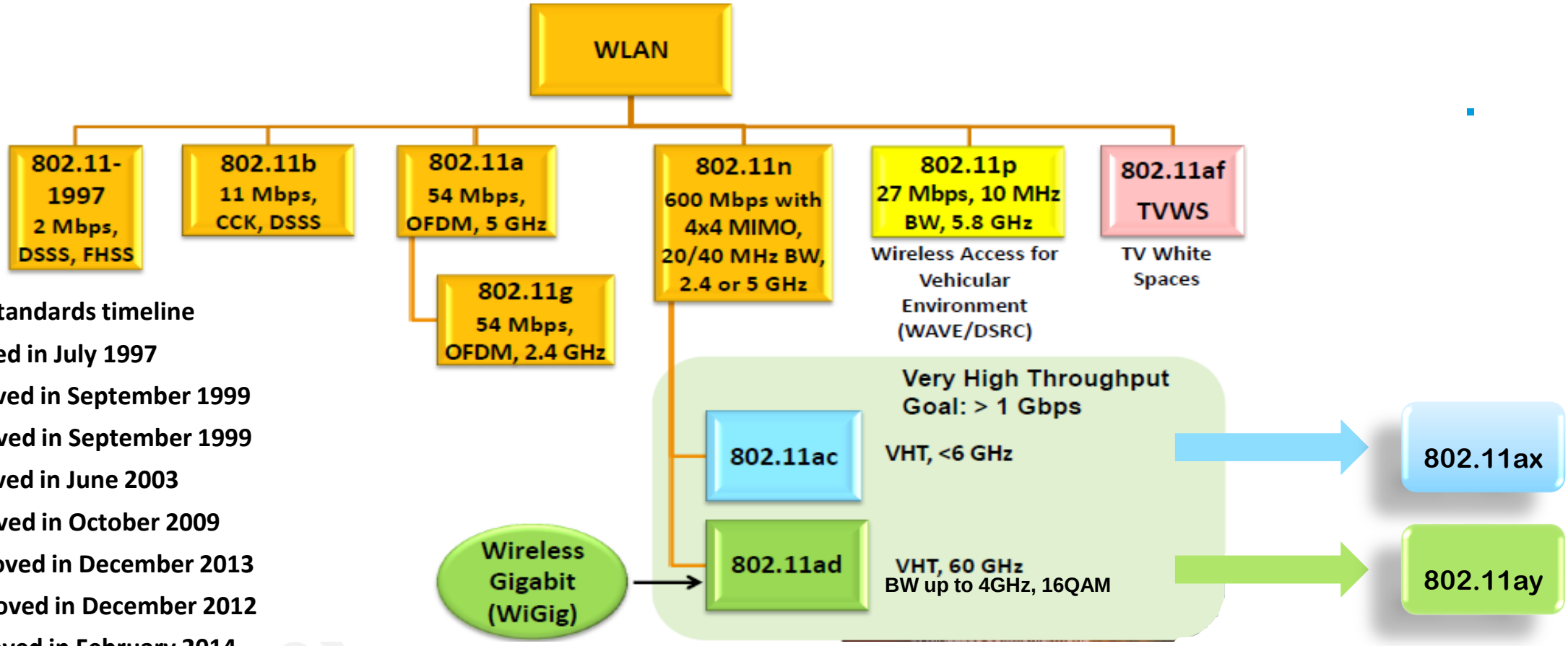
5G NR Band Deployment Priorities by Geography

Driven by LTE Leader



IEEE 802.11 Timeline

11ax is the advance version of 11ac



- The IEEE 802.11 standards timeline
  - 802.11 approved in July 1997
  - 802.11a approved in September 1999
  - 802.11b approved in September 1999
  - 802.11g approved in June 2003
  - 802.11n approved in October 2009
  - 802.11ac approved in December 2013
  - 802.11ad approved in December 2012
  - 802.11af approved in February 2014
  - 802.11ah approved in 2016
  - 802.11ax expected to be approved in 2019
  - 802.11ay expected to be approved in 2017

WiFi Generations

Identifying device technology

A new naming system identifies Wi-Fi® generations by a numerical sequence

Wi-Fi 6 identifies devices that support 802.11ax technology

Wi-Fi 5 identifies devices that support 802.11ac technology

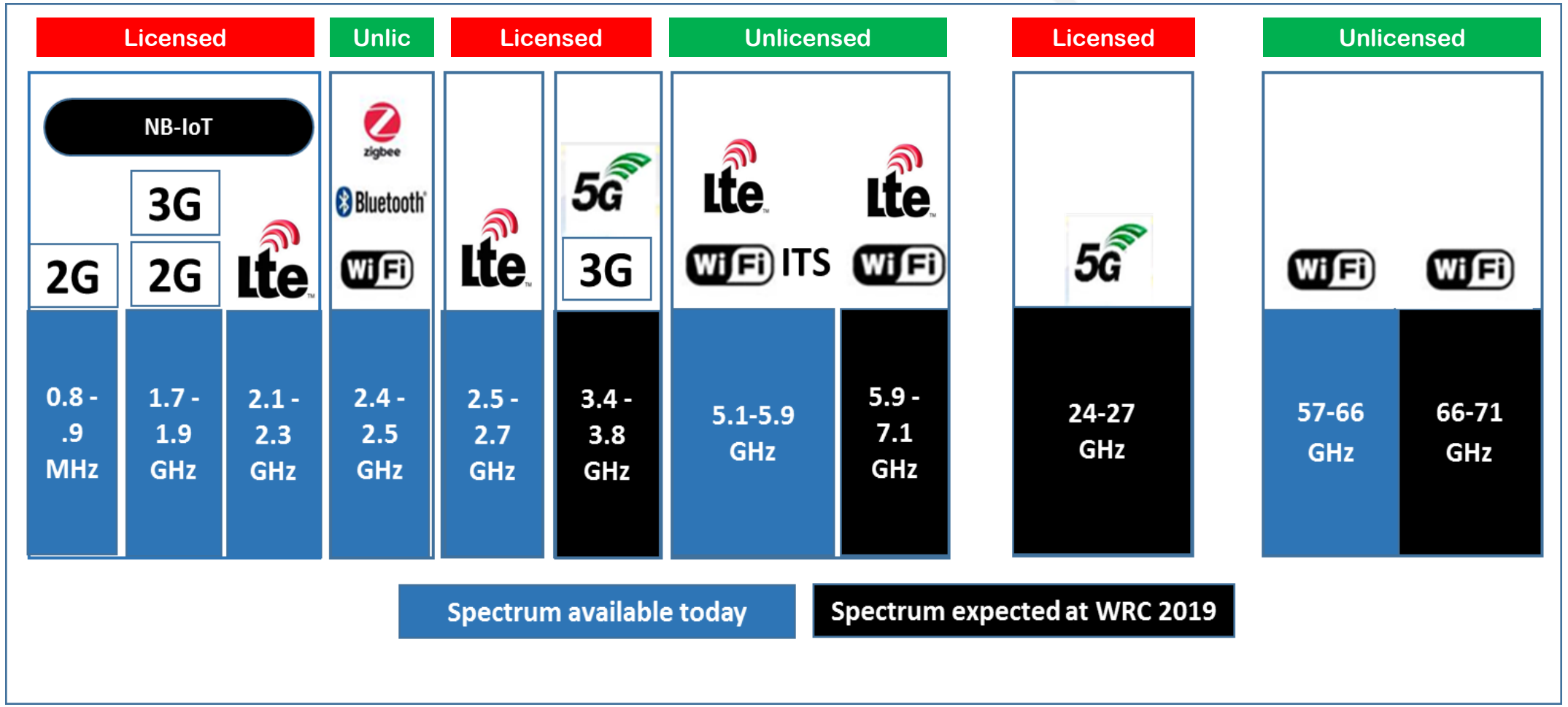
Wi-Fi 4 identifies devices that support 802.11n technology

Generation of network connection	Sample user interface visual
Wi-Fi 6	
Wi-Fi 5	
Wi-Fi 4	

Numbering is better!! -By Steven Jobs

Spectrum Availability

Licensed vs Unlicensed

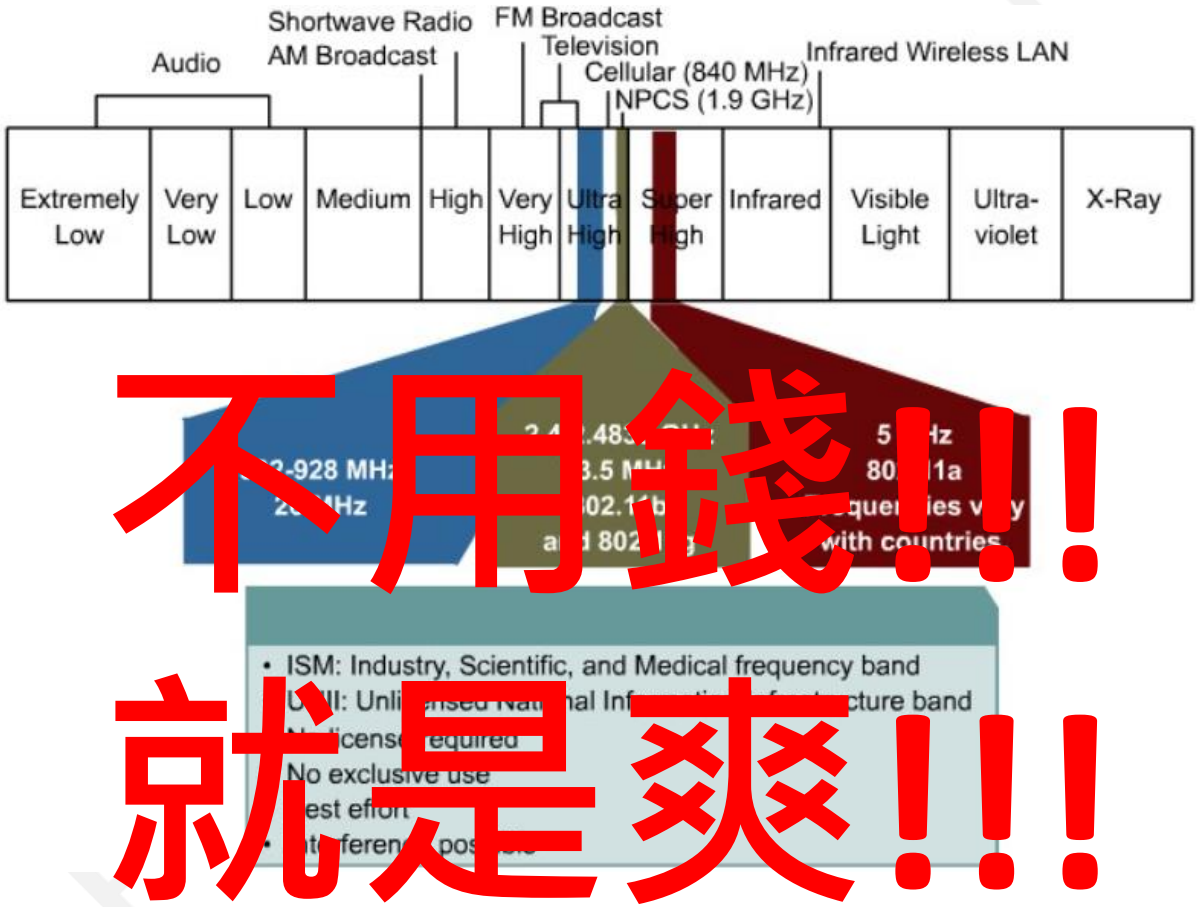


Cost is matter

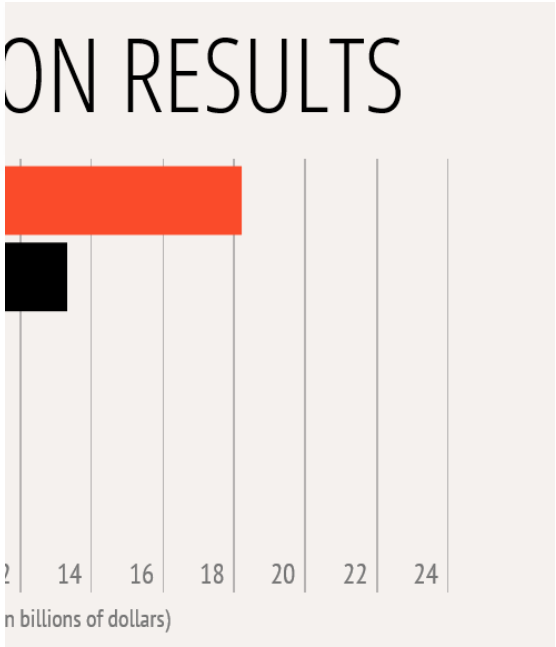
Frequency spectrum is not FREE but WiFi

The 4G auction took plac

Wining bidder	Sp
Everything Everywhere Ltd	2 x 5 MHz 2 x 35 MHz
Hutchison 3G UK Ltd	2 x 5 MHz
Niche Spectrum Ventures Ltd (a subsidiary of BT Group plc)	2 x 15 MHz 1 x 25 MHz
Telefonica UK Ltd	2 x 10 MHz (coverage
Vodafone Ltd	2 x 10 MHz 2 x 20 MHz 1 x 25 MHz
Total	

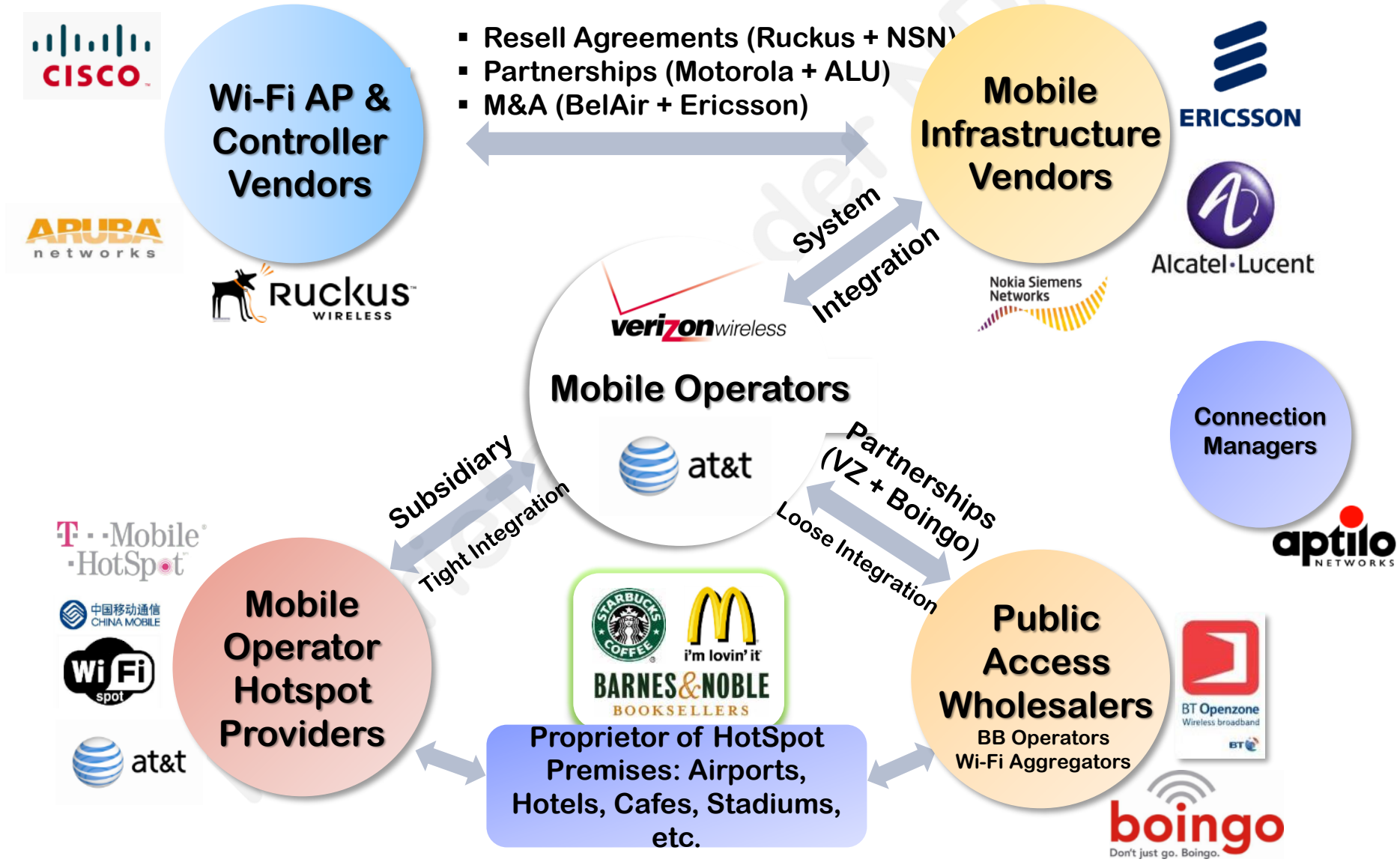


record $45 billion in 2015
.780 MHz, 2155-2180 MHz)



不用錢!!!
就是爽!!!

Win-Win Solution – WiFi Offload



Why 802.11ax

What are the concerns with 802.11ac?

- The need for a new Wi-Fi standard targeted for a large number of users has become evident.
  - Offices, Shopping Malls, Restaurants, Schools, Concert Halls, Sports Stadiums and etc.
- Wi-Fi platforms have traditionally focused on theoretical higher peak speeds. In reality, a network delivers top speed for a single user (or a few users) doesn't satisfy the need today.

Can I get some Wi-Fi…. Please !!!

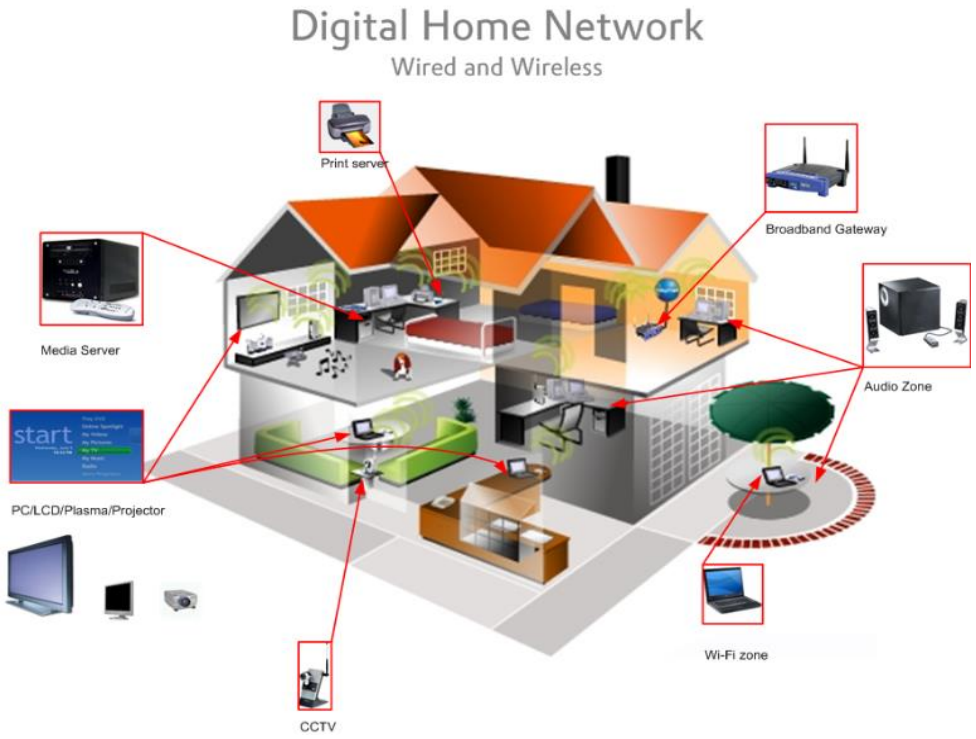
20,000 seats = 800AP's
25 client devices / AP
➢ 10-15Mbps/device
(one stream, by math)

- www.qualcomm.com
- www.Keysight.com

Why 802.11ax

What are the concerns with 802.11ac?

- Even for a regular household, the number of Wi-Fi enabled devices has grown (and expected to grow dramatically)
  - ❑ 2012 – 8
  - ❑ 2017 – 24
  - ❑ 2022 – 50



- With tens/hundreds of clients competing for connections, data packets lost due to interferences and subsequent retransmissions lower the actual throughput and reduce battery life.

- Applications and services with diverse needs –
  - ❑ High data rate for video streaming
  - ❑ Robust connection for monitoring devices
  - ❑ Indoor and outdoor applications

- www.qualcomm.com
- www.Keysight.com

Why 802.11ax

What are the concerns with 802.11ac?

- 802.11ax, also known as High-Efficiency (HE) Wireless, aims to improve the average throughput per user by a factor of at least 4 times in dense user environments through defining WLAN MAC and PHY enhancements.
- 802.11ax is designed to deliver all users with a dramatically better user experience, in all possible scenarios.
- 802.11ax also aims to improve indoor as well as outdoor coverages.

Yeah!!!
That's what
I'm talking
about!!!

- www.qualcomm.com
- www.Keysight.com

Who is the 11ax pioneers

Announcement from Chipset Vendors

QUALCOMM®

MARVELL®

BROADCOM

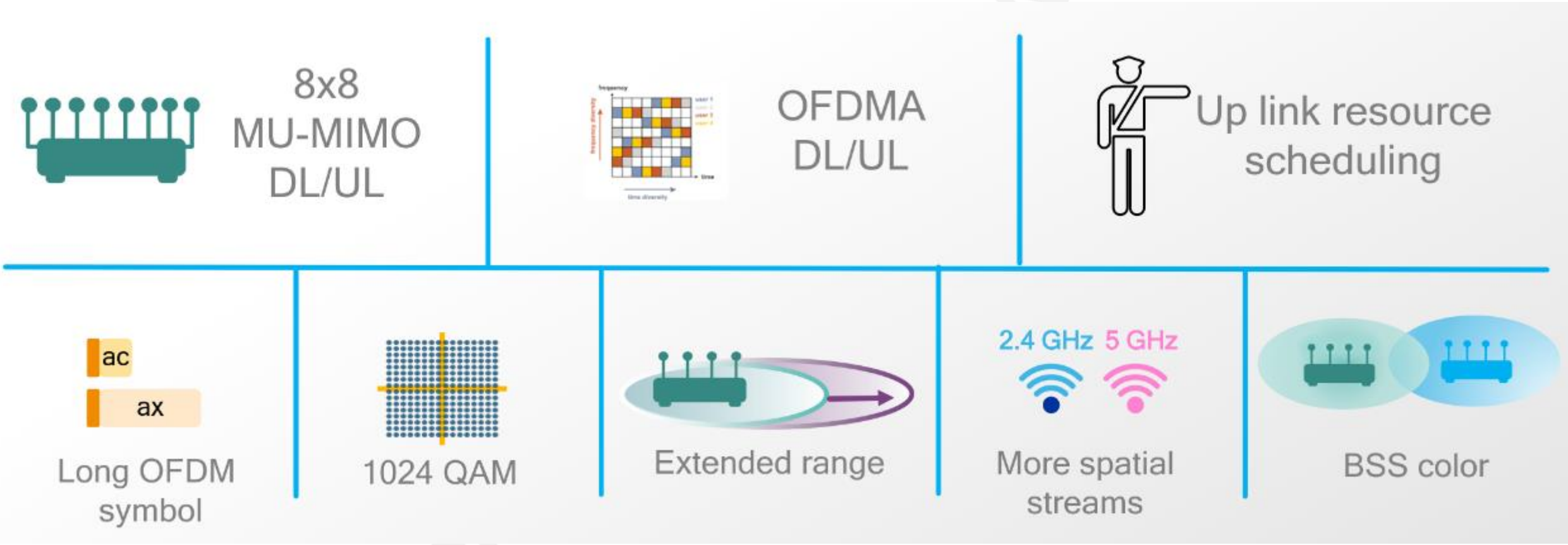
maxWIFI

THE 6TH GENERATION OF WI-FI TECHNOLOGY

intel®

Quantenna

Technologies Building Blocks of 802.11ax

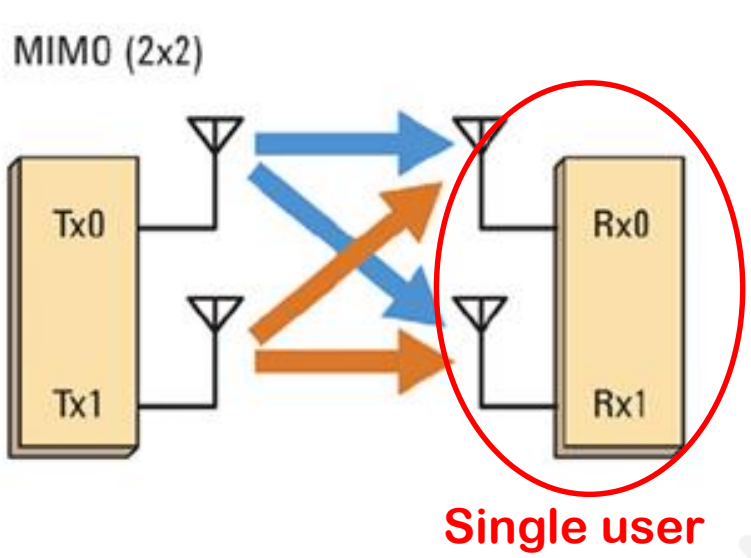


* www.qualcomm.com

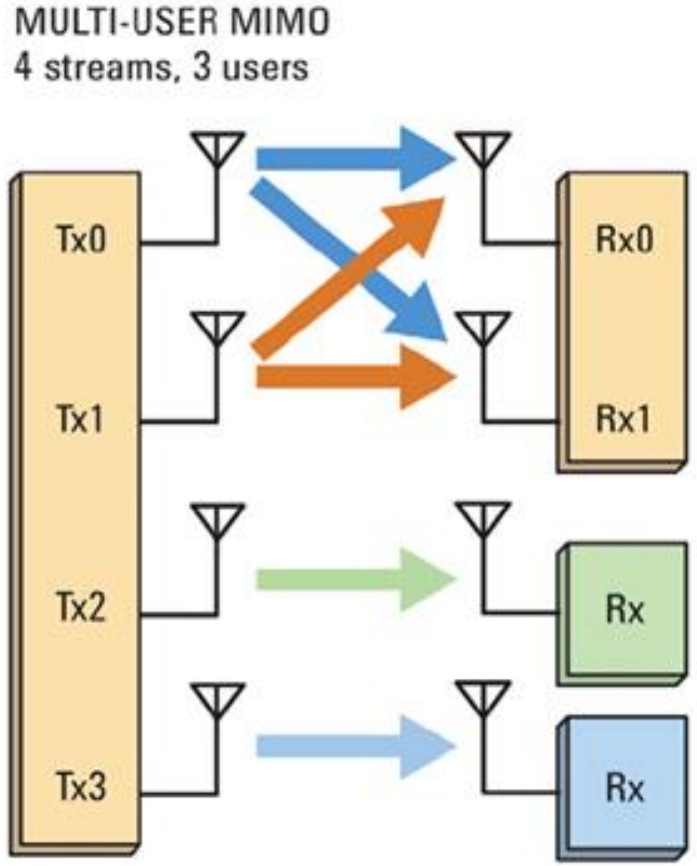
802.11ax – MU-MIMO

802.11ax supports downlink and uplink MU-MIMO

- SU-MIMO : Supports one user at a time
- MU-MIMO : Can support multiple users simultaneously



Single user

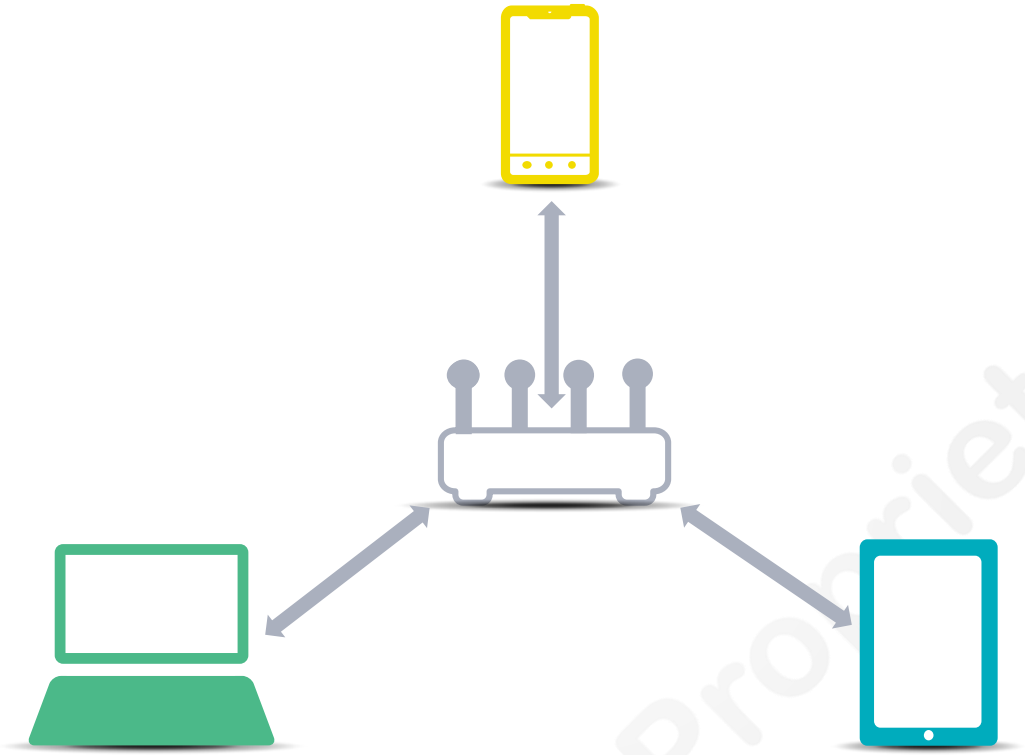


Both Signal User (SU)-MIMO and Multi-User (MU)-MIMO can support multiple users

802.11ax – MU-MIMO

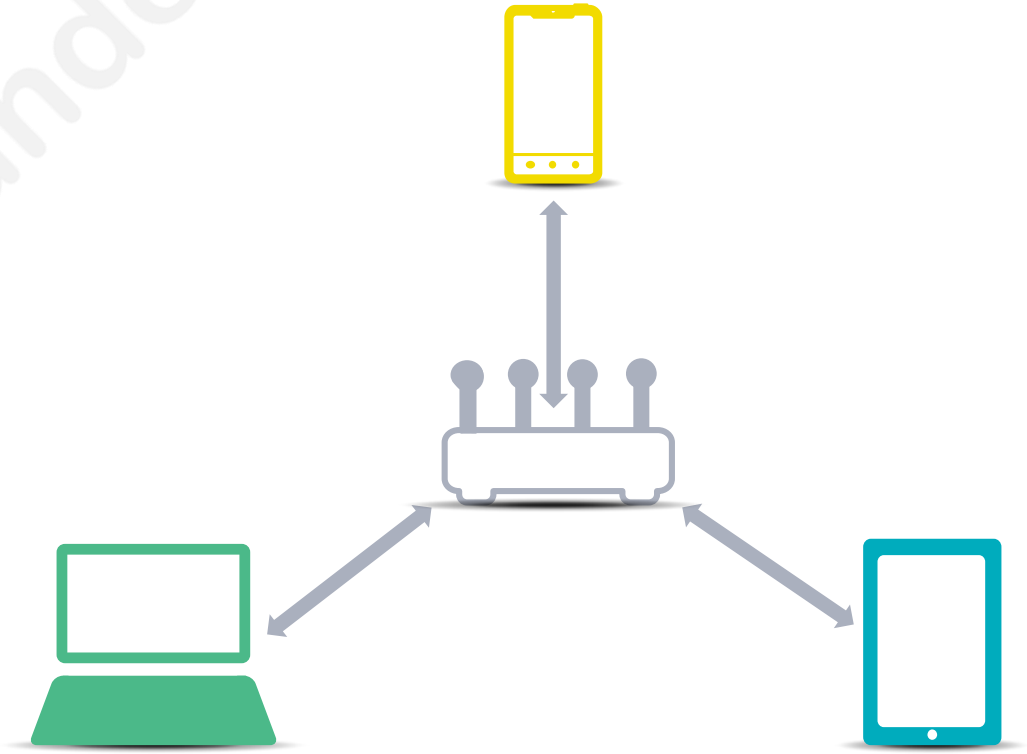
Single-User MIMO

Serves one device at a time



Multi-User MIMO

Multi-user beamforming (MUBF) serves multiple devices simultaneously

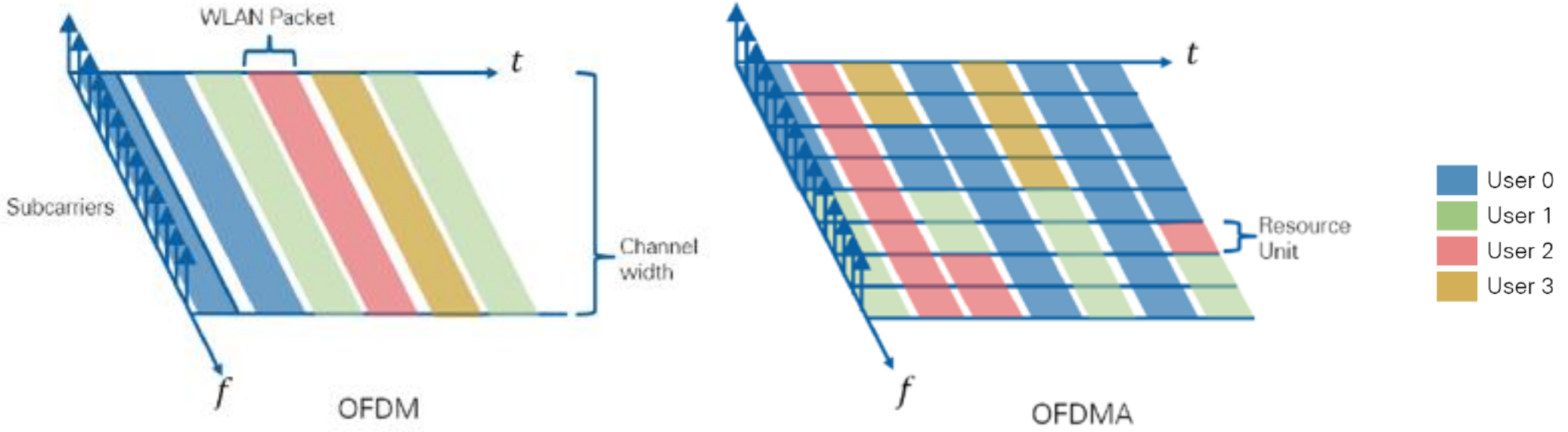


- Spatial re-use multiplies available capacity (2-3x)
- Reduces wait time for all clients

802.11ax – OFDMA

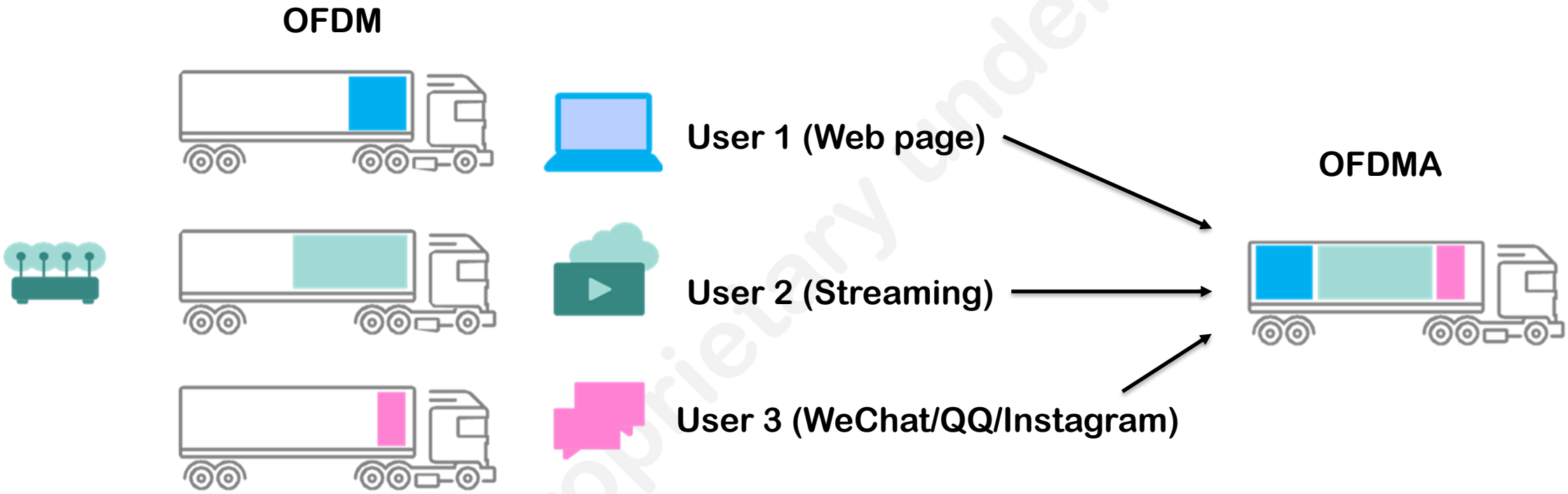
OFDM vs OFDMA

- **OFDM (Multiplexing)**
  - One user is assigned full OFDM symbol with all the data subcarriers as well as pilot subcarriers
  - Used in fixed WiMAX and 802.11a/g, 802.11n and 802.11ac
- **OFDMA (Multiple Access)**
  - Multiple users are assigned to an OFDM symbol
  - One user is assigned to unique one or more Resource Units (sub-channels). A resource unit is composed of distributed or contiguous subcarriers based on OFDMA type.
  - For 802.11ax, minimum sub-channel = 2MHz, maximum sub-channel = 80MHz
  - Used in LTE down link and 802.11ax (downlink and uplink)



802.11ax – OFDMA

OFDM vs OFDMA



Fixed Overhead vs. Efficient Payload Delivery

OFDMA and MU-MIMO Are Complementary

Application Dependent

OFDMA

OFDMA Efficiency Improvement

OFDMA Reduces Latency

Ideal for Low BW Apps

MU-MIMO

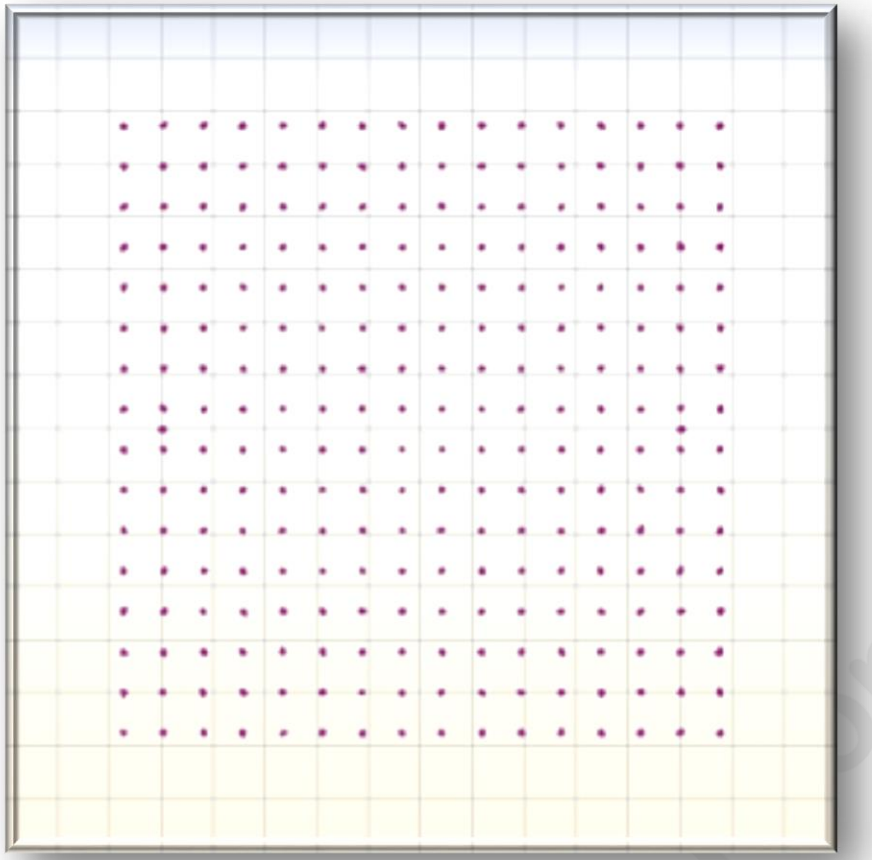
MU-MIMO Capacity Improvement

MU-MIMO Higher Speeds

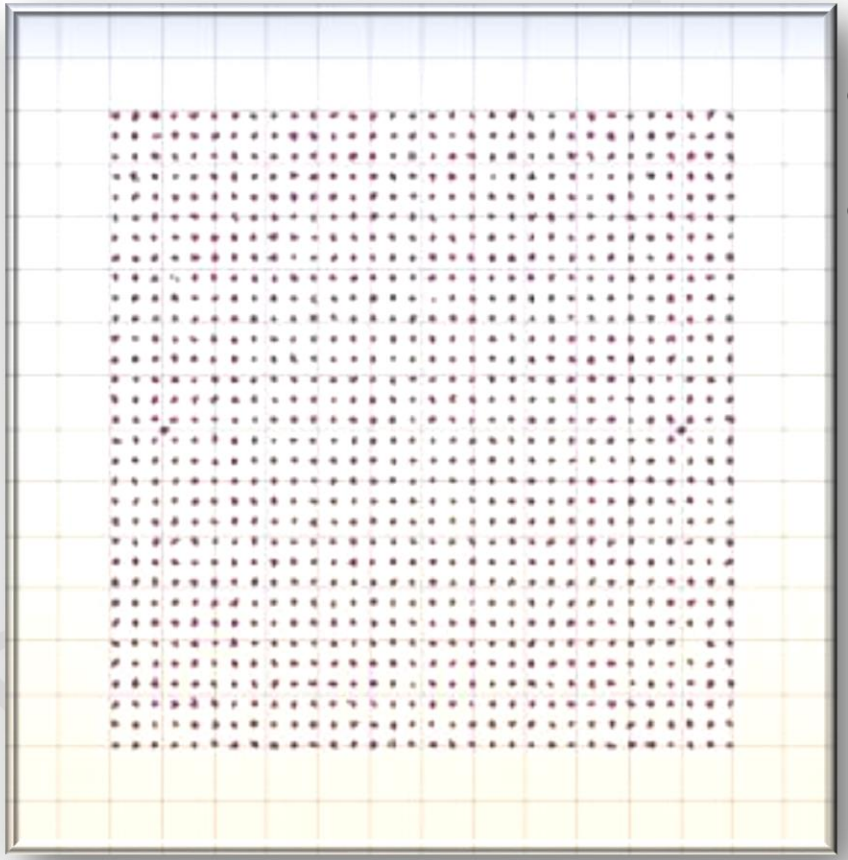
Ideal for High BW Apps

802.11ax – 1024QAM

1024QAM – a 25% throughput enhancement from 256QAM



256QAM



1024QAM

- 802.11ax supports 1024QAM (MCS10 and MCS11)
- For 1024QAM, each symbol carries 10 bits of information (vs. 8 bits for 256QAM)

http://www.LitePoint.com
http://www.ni.com

802.11ax – 1024QAM

MCS supported by recently 802.11 standards

	MCS	Modulation	Coding Rate	EVM (dB)
802.11n	0	BPSK	1/2	-5
	1	QPSK	1/2	-10
	2	QPSK	3/4	-13
	3	16-QAM	1/2	-16
	4	16-QAM	3/4	-19
	5	64-QAM	2/3	-22
	6	64-QAM	3/4	-25
	7	64-QAM	5/6	-27
802.11ac	8	256-QAM	3/4	-30
	9	256-QAM	5/6	-32
802.11ax	10	1024-QAM	3/4	-35
	11	1024-QAM	5/6	-35

* Rohde & Schwarz white paper

802.11ax – Uplink Resource Scheduler

Instead of the traditional unmanaged approach, where users compete with one another to send data in uplink, 802.11ax schedules them so that they don't clash with each other. This managed approach results in better resource utilization and an impressive increase in efficiency.

Contention Based Resource Allocation

- Uncoordinated Resource Management
- Devices Compete Until They Succeed
- Ideal for Single AP Scenario

Scheduled Based Resource Allocation

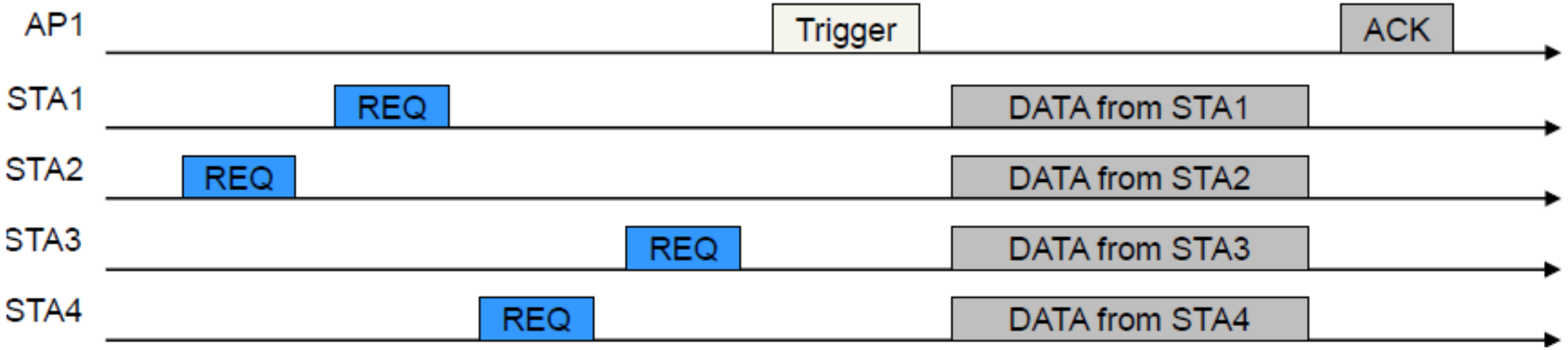
- Uplink Resource Allocation Managed by AP
- Increased Capacity and Better User Experience
- Ideal for a Dense Scenario

http://www.qualcomm.com

802.11ax – Uplink Resource Scheduler

Multi-User Uplink Operation

- AP sends a trigger frame to all users containing information of number of spatial streams and/or the OFDMA allocations of each user. The trigger frame also contains detailed instructions to each user on power control, when to start and stop transmitting and etc.
- Once the AP receives the frames from all users, it sends them back a block ACK to finish the operation
- This main design to achieve 4X higher average per-user throughput in dense user environments for uplink.



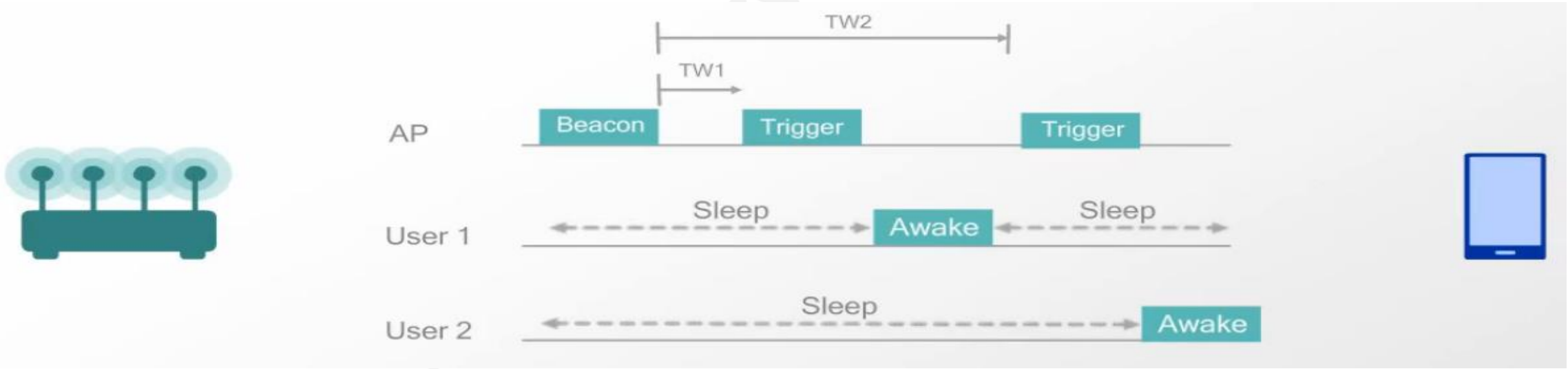
Uplink Multiuser MIMO Trigger Process

https://arxiv.org/pdf/1611.06609.pdf
http://www.qualcomm.com

802.11ax – Target Wake-up Time

Improve client station battery life

- An 802.11ax AP can negotiate with the participating clients the use of the Target Wake Time (TWT) function to define a specific time or set of times for individual stations to access the medium.
- 802.11ax clients may use TWT to reduce energy consumption, entering a sleep state until their TWT arrives. Furthermore, an AP can additionally devise schedules and deliver TWT values to clients without individual TWT agreements between them. The standard calls this procedure Broadcast TWT operation and could substantially improve client device battery life.



http://www.qualcomm.com
http://www.ni.com

Technology Landscape Fragmented

	Short Range	Local Area	Wide Area
Range (typical)	< 10m/30ft	< 100m/300ft	Outdoor (Km/Miles)
Content distribution Focus on high data rates	Bluetooth	Wi Fi, Wi Fi DIRECT, IEEE 802.11ax, .11ah: HaLow	GSM, LTE, 5G
Sense & control Low energy/long battery life	Bluetooth SMART	zigbee, ULE ALLIANCE	NB-IoT, GPRS
Proprietary solutions	ANT+	Sub-GHz, enocean	SIGFOX, LoRa, INGENU, WEIGHTLESS
Typical applications	**Personal appliances** (wrist band, smart watch, step counter, keyboard, mouse, pointer, etc.)	**Indoor networks** (internet, email, phone, security, energy management, home monitoring, etc.)	**Outdoor networks** (phone, chat, internet, smart city, industry 4.0, agriculture, smart logistics, etc.)

Conclusions

Who is going to win?

- 802.11ax, also called High-Efficiency Wireless (HEW), has the challenging goal of improving the average throughput per user by a factor of at least 4X in dense user environments. This new standard focuses on implementing mechanisms to serve more users a consistent and reliable stream of data (average throughput) in the presence of many other users.
- 5G is a novel technology which built on foundation of 4G LTE. The biggest challenge of 5G is standardization. After all, it's critical to ensure universal interoperability of this new technology. Furthermore, the implementation cost is terrific high. It is expected that 5G technology will be able to serve billions of connected devices in a single network, addressing the growing IoT market where the amount of wireless sensors will explode in conjunction with real-time oriented applications. 5G is meant to minimize the latencies.
- Both 5G and Wi-Fi have very particular characteristics that will be beneficial for connecting 「devices」 to the internet. So, the Telecom Carriers and Operators that best can exploit both technologies to its advantage and can define and execute a strategy that leverages them both, will become the winner. Seen from this perspective, the ultimate winner of these technology battles will be the end-user.

Thank You

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all around you

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