WIRELESS INNOVATION DAY TAIWAN

Wi-Fi IN FOCUS

A technology deep dive into its state and future

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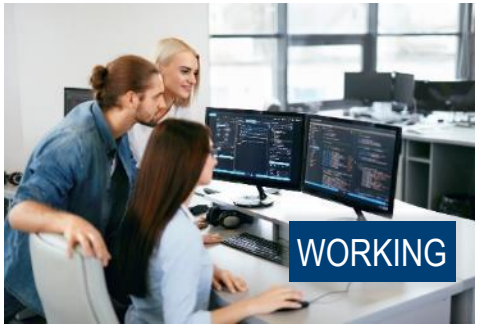
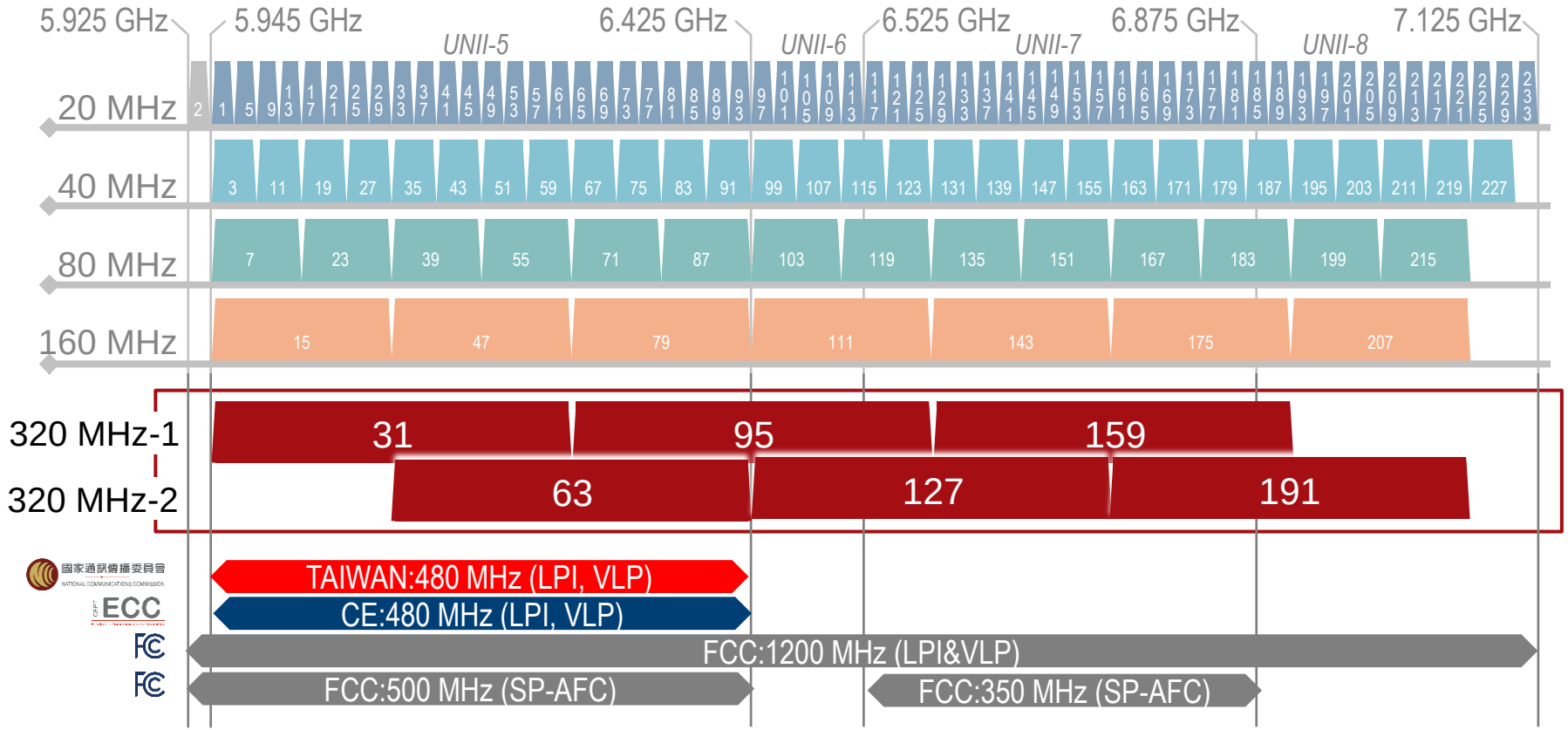
Make ideas real

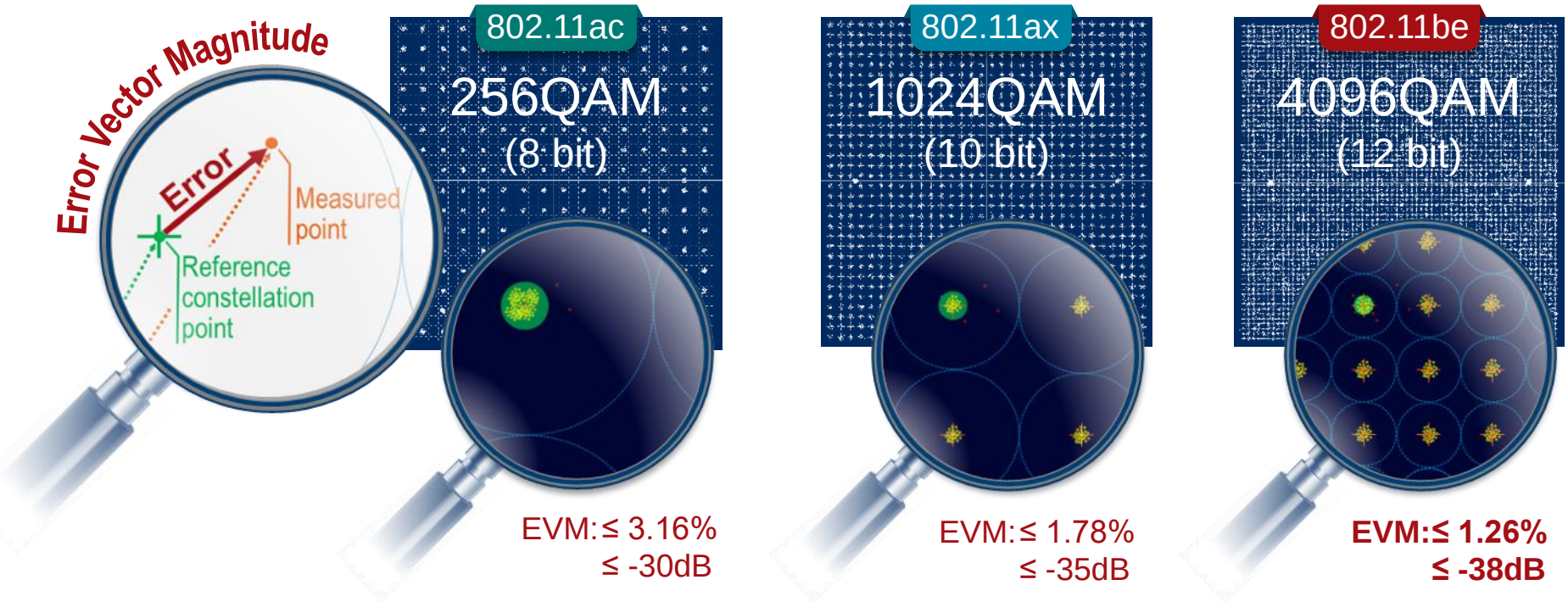


The 7th generation of Wi-Fi for Extreme High Throughput (EHT) at home, offices and factories

A few overlapping 320 MHz channels in the 6 GHz band

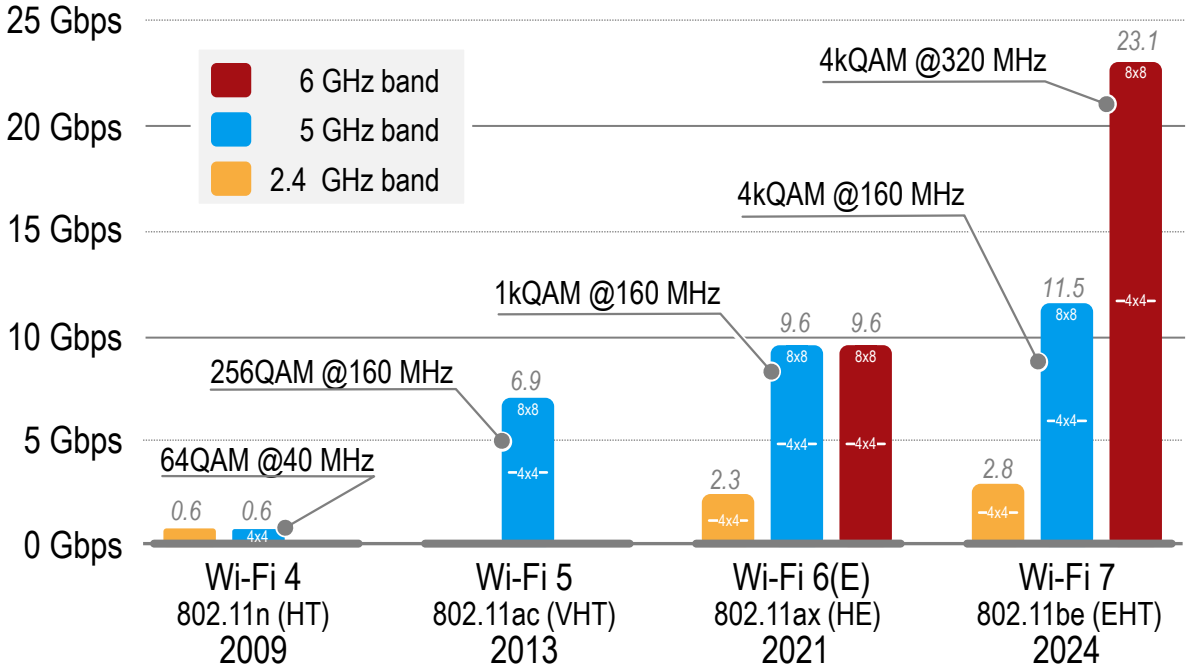


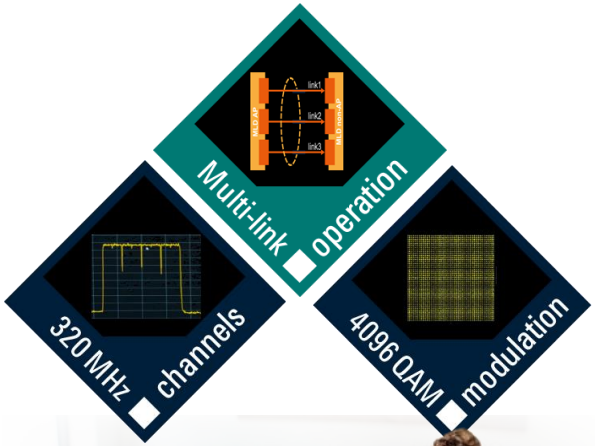
802.11be elevates RF performance requirements and requires enhanced test equipment performance and accuracy



Achieving extreme high throughput (EHT) with IEEE802.11be

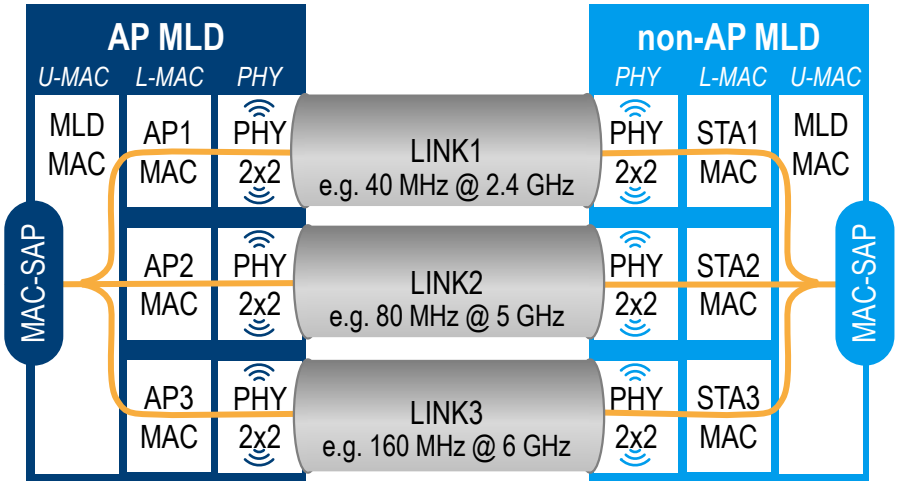
Evolution of maximum achievable throughput per single link in all bands





Reference model for multi-link operation (MLO) of multi-link devices (MLD) to improve latency, throughput and reliability

Multi-link operation (MLO) enables a non-AP multi-link device (MLD) to discover, authenticate, associate, and set up one or more links with an AP MLD.



Each link enables **channel access** and **frame exchanges** between the non-AP MLD and the AP MLD based on the supported capabilities exchanged during the association.

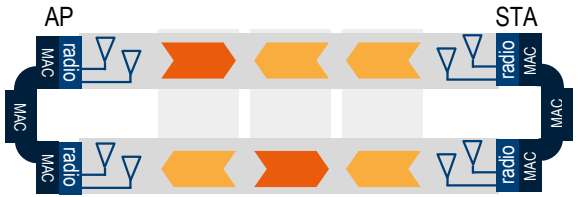
Multi-link element (MLE) information is used to setup and manage MLO – added to beacons, probe request and reconfiguration

Element ID	Length	Element ID extension	Multi-link control	Common info	Link info

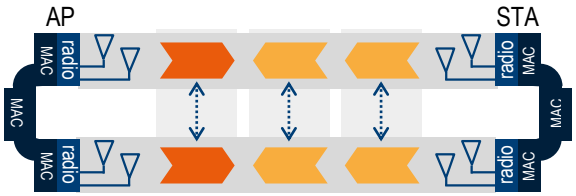
Multi-link operation mode in the nutshell

Multi-link multi-radio (MLMR)

Simultaneous Tx & Rx (STR) ☑ | Nonsimultaneous Tx & Rx (NSTR)



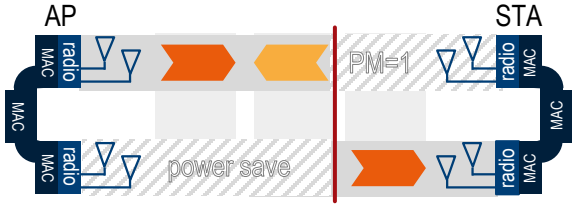
Simultaneous Tx/TX, Rx/Rx and **Tx/Rx**



In-synch use of link pair Tx/Tx or Rx/Rx

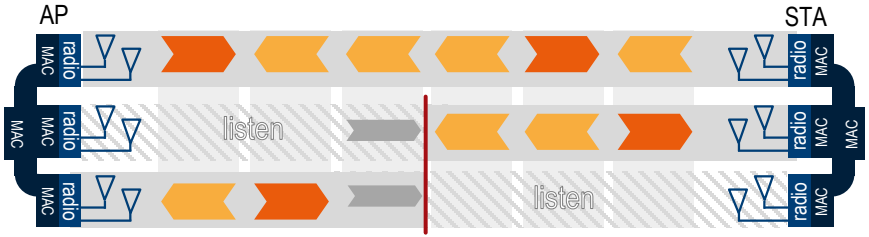
Multi-link single-radio (MLSR)

one active link at the time only



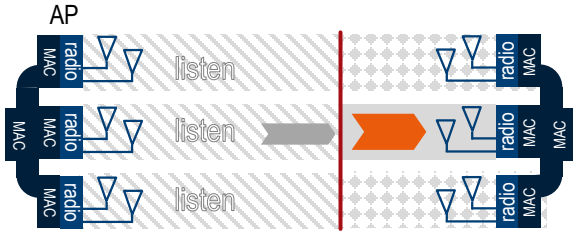
Single link operation, other(s) power save (PM=1)

Enhanced MLMR (EMLMR)



Dynamically configure the EMLMR links (# spatial streams, MSC) from listen to “full power”

Enhanced MLSR (EMLSR) ☑

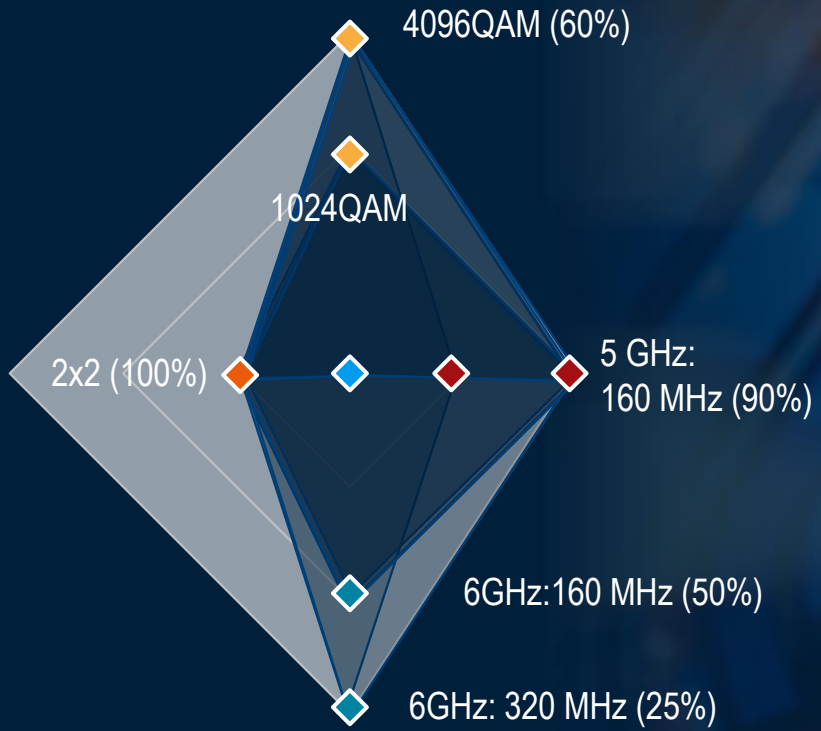


STA is able to listen on links and switch between

Over two generations a three fold increase of max throughput

	Wi-Fi 5 (802.11ac) *Very High Throughput (VHT)*	Wi-Fi 6E (802.11ax) *High Efficiency (HE)*	Wi-Fi 7 (802.11be) *Extreme High Throughput (EHT)*
Supported bands	5 GHz	2 GHz, 5 GHz, **6 GHz**	2 GHz, 5 GHz, 6 GHz
Channel bandwidth (MHz)	20, 40, 80, 80+80, 160	20, 40, 80, 80+80, 160	20, 40, 80, 160, **320**
Transmission scheme	OFDM	OFDM, $OFDMA_{RU}$	OFDM, $OFDMA_{RU/MRU}$
Subcarrier spacing	312.5 kHz	78.125 kHz	78.125 kHz
Guard interval	0.4 µs, 0.8 µs	0.8 µs, 1.6 µs, 3.2 µs	0.8 µs, 1.6 µs, 3.2 µs
Spatial streams	8x8 (incl. DL-MU-MIMO)	8x8 (incl. MU-MIMO)	8x8 (incl. MU-MIMO)
Modulation (highest)	256QAM (8 bit)	1024QAM (10 bit)	**4096QAM (12 bit)**
Max PHY throughput	**6.9 Gbps**	**9.6 Gbps**	**23.1 Gbps**

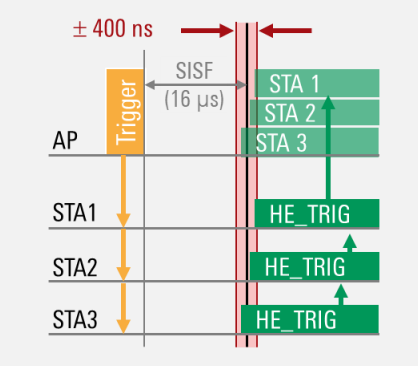
Unlocking the future: Today's mobile phones embrace Wi-Fi 7



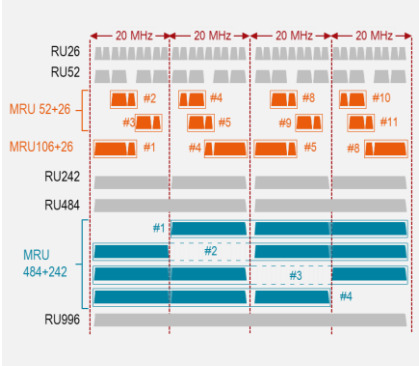
Based on Wi-Fi7 phones from Apple, Asus, Google, Motorola, Nubio, Samsung

The test Challenges:
A new complexity and more variations with Wi-Fi6/7

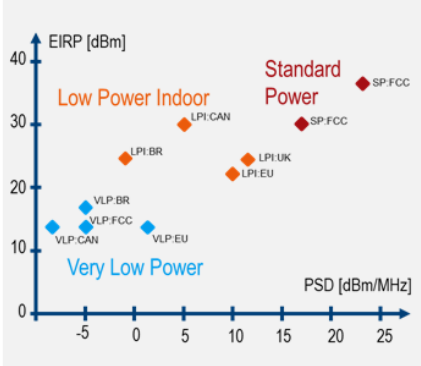
Trigger based



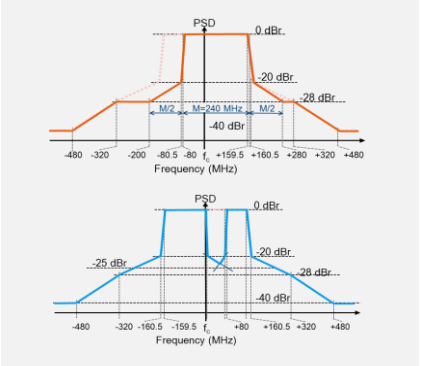
Resource Units



Spectrum Management



Puncturing



Multi-link Operation (MLO), introduced in Wi-Fi7, ask for new measurements (interference, timing, power save) in all different MLO modes and possible channel/band combinations

The next generation of Wi-Fi targeting Ultra High Reliability

Extended reality | Factory control | Internet of Things | Enterprise networks




UHR ultra high reliability 8

IEEE 802.11bn

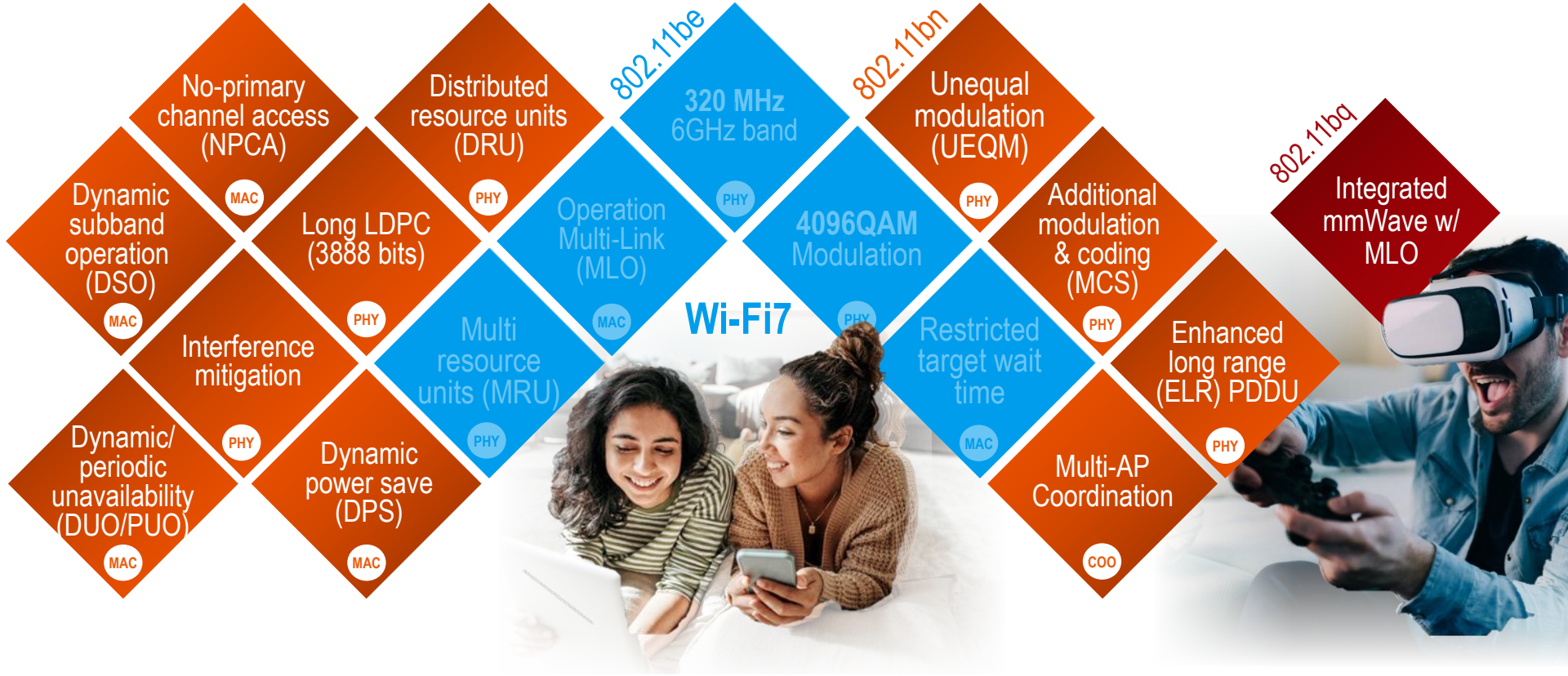
Enhancements for Ultra High **Reliability:**

- increasing throughput by 25%
- reducing latency by 25%
- reducing packet loss probability especially for seamless transition between BSS

Reduce power consumption for APs and improved P2P

Amendment 802.11bn applies to carrier frequency operation between 1 GHz and 7.250 GHz and backward compatibility

Fine tuning Wi-Fi on the foundation of 11be with 11bn

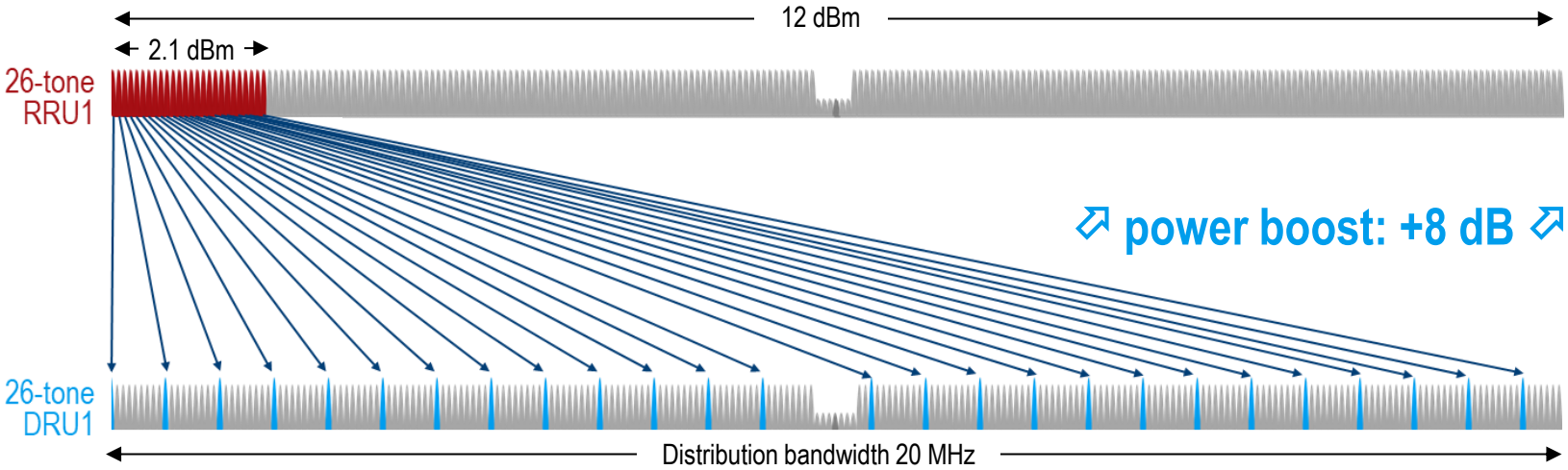


Distributed Resource Unit (DRU)

Distributed RU (DRU) for trigger-based UL OFDMA transmission boost maximum transmission power

FCC Low Power Indoor (LPI) Client (6XD)

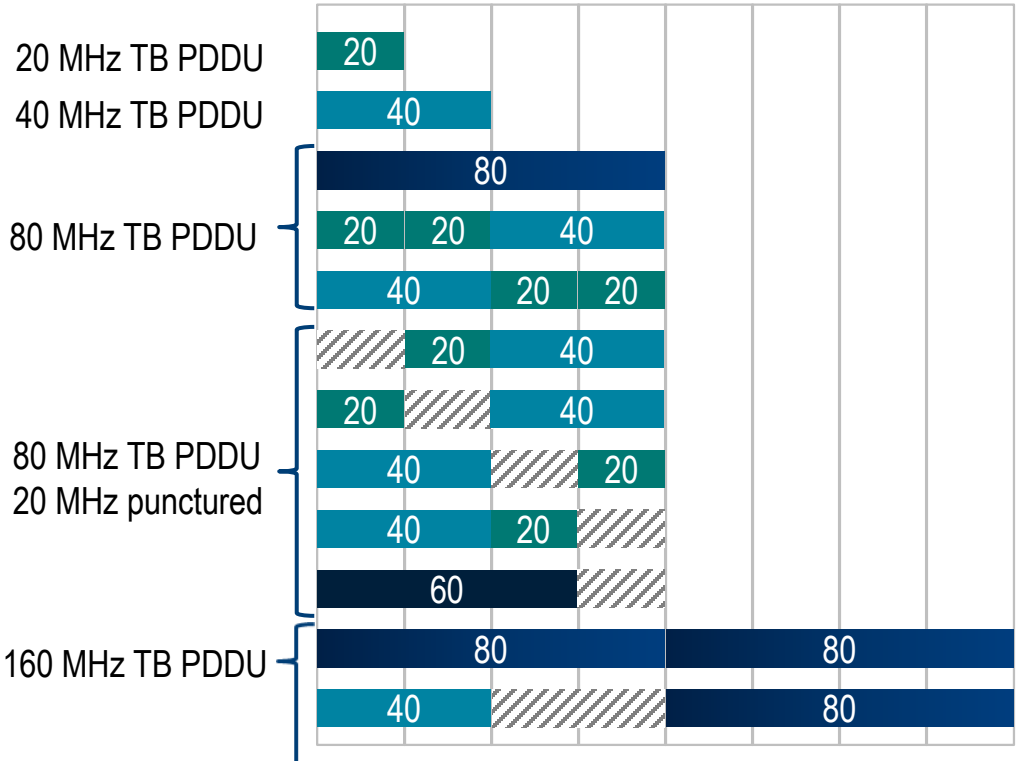
EIRP ≤ 24 dBm, **PSD ≤ - 1 dBm/MHz** ⇨ rRU26: 13 tones per MHz ⇨ **-12 dBm per tone** ⇨ $EIRP_{26}$ = 2.1 dBm



EIRP ≤ 24 dBm, **PSD ≤ - 1 dBm/MHz** ⇨ DRU26: 2 tones per MHz ⇨ **-4 dBm per tone** ⇨ $EIRP_{26}$ = 10.1 dBm

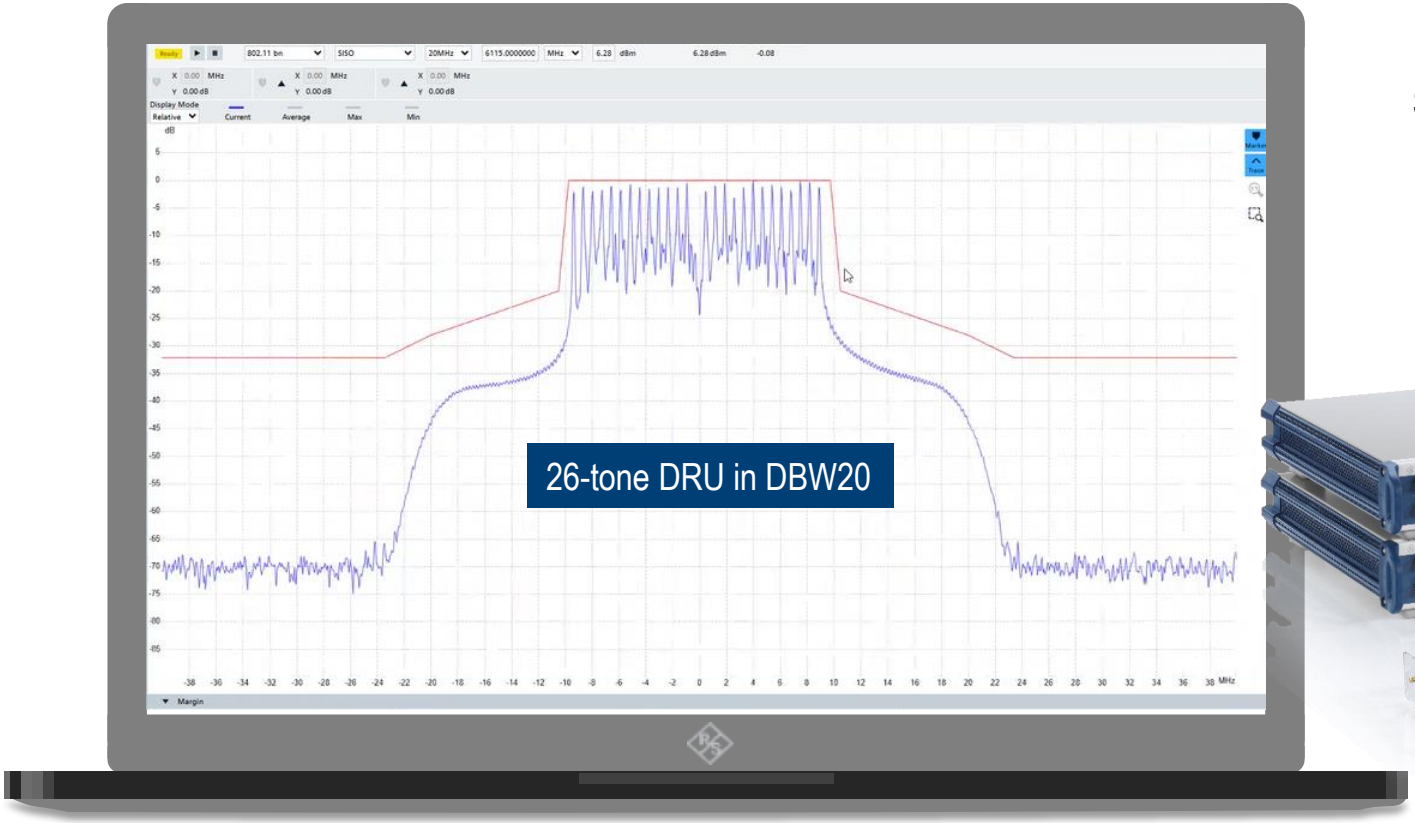
RRU regular RU
DRU distributed RU

DRUs limitations by spreading of DRU tones in distribution bandwidth (DBW: 20, 40, 60, 80 MHz).



- A DRU transmission is allowed only in an **OFDMA UHR TB PPDU,** UL MU MIMO is disallowed
- Maximum two spatial streams are allowed.
- For a 160 MHz UHR TB PPDU and a 320 MHz UHR TB PPDU, a hybrid mode where DRUs and Regular RUs (RRUs) are simultaneously used in one UHR TB PPDU is allowed.
- For a UHR TB PPDU (160/320 MHZ) with the hybrid mode, either DRU or RRU are used within each 80 MHz frequency subblock and DRUs and RRUs are not mixed within a certain 80 MHz frequency subblock. The minimum RRU size is 242 in the hybrid mode.

Example 26-toneDRU in DBW20 measurement on R&S®CMP180



Showed first in March 2025

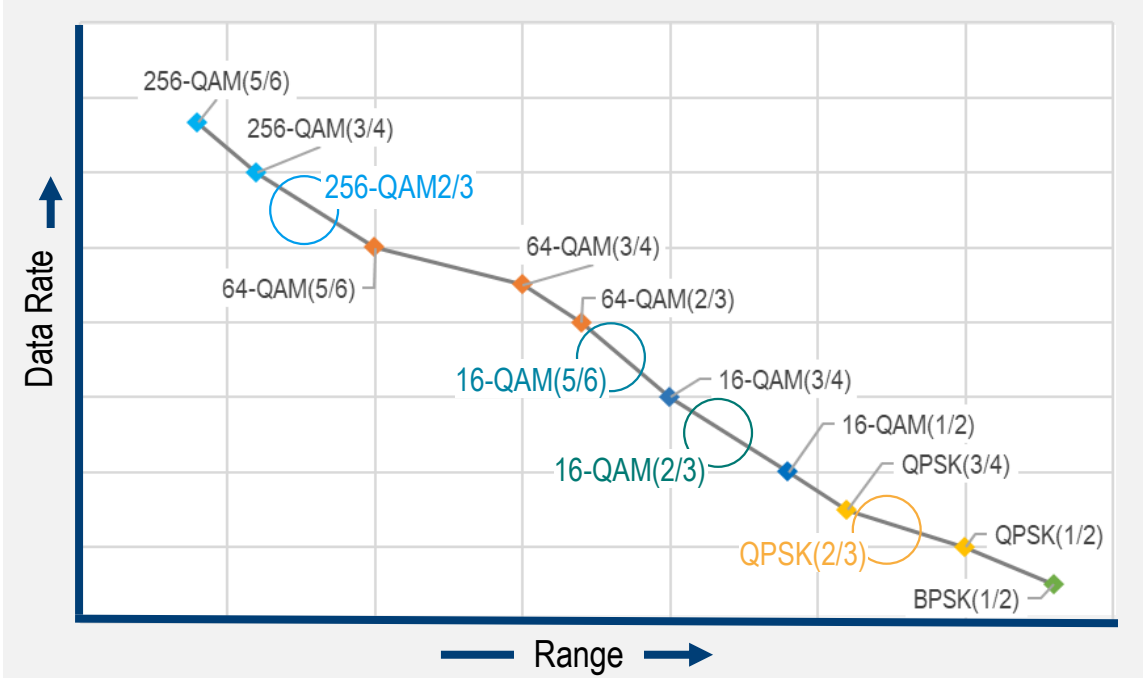
MWC25

embeddedworld
Exhibition&Conference

Closing some sensitivity Gaps

Introducing finer rate selections (MSCs) brings more options to „tune“ Rate versus Range (RvR) and helps also UEQM

There are some gaps in the RvR plot

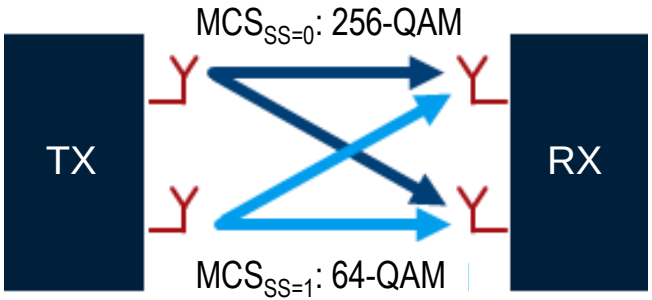


	1/2	2/3	3/4	5/6
BPSK	MCS0			
QPSK	MCS1	NEW	MCS2	
16QAM	MCS3	NEW	MCS4	NEW
64QAM		MCS5	MCS6	MCS7
256QAM		NEW	MCS8	MCS9
1024QAM			MCS10	MCS11
4096QAM			MCS12	MCS13

Unequal Modulation (UEQM)

Re-visiting Unequal Modulation (UEQM) to improve SU MIMO performance with beamforming.

- UEQM is used to improve performance (overall throughput) by adapting the modulation & coding scheme used on each spatial stream based on its channel quality.
- Coding stays the same, but modulation can be adapted



Unequal Modulation (UQAM)
e.g. 2ss, [256-QAM, 64-QAM]
e.g. 4ss, [1K-QAM, 1K-QAM, 256-QAM, 64-QAM]

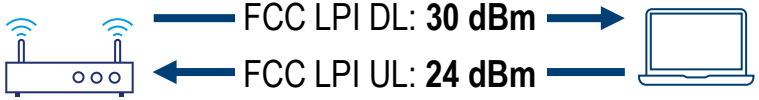
	1st	2nd	3rd	4th
2x2	S	S-1		
	S	S-2		
3x3	S	S	S-1	
	S	S	S-2	
	S	S-1	S-2	
4x4	S	S	S	S-1
	S	S	S	S-2
	S	S	S-1	S-2
	S	S-1	S-1	S-2

S	Constellation index
6	4096-QAM
5	1024-QAM
4	256-QAM
3	64-QAM
2	16-QAM
1	QPSK

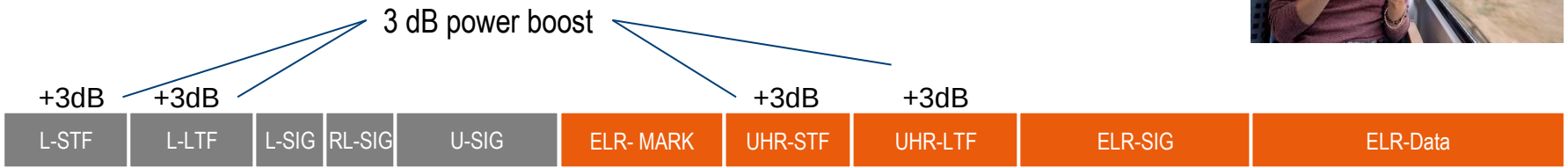
Enhanced Long Range (ELR)

Enhanced Long Range (ELR) PPDU

Need to improve the range of uplink to overcome the link budget imbalance between downlink and uplink



Link budget difference between downlink and uplink can be 6 dB.



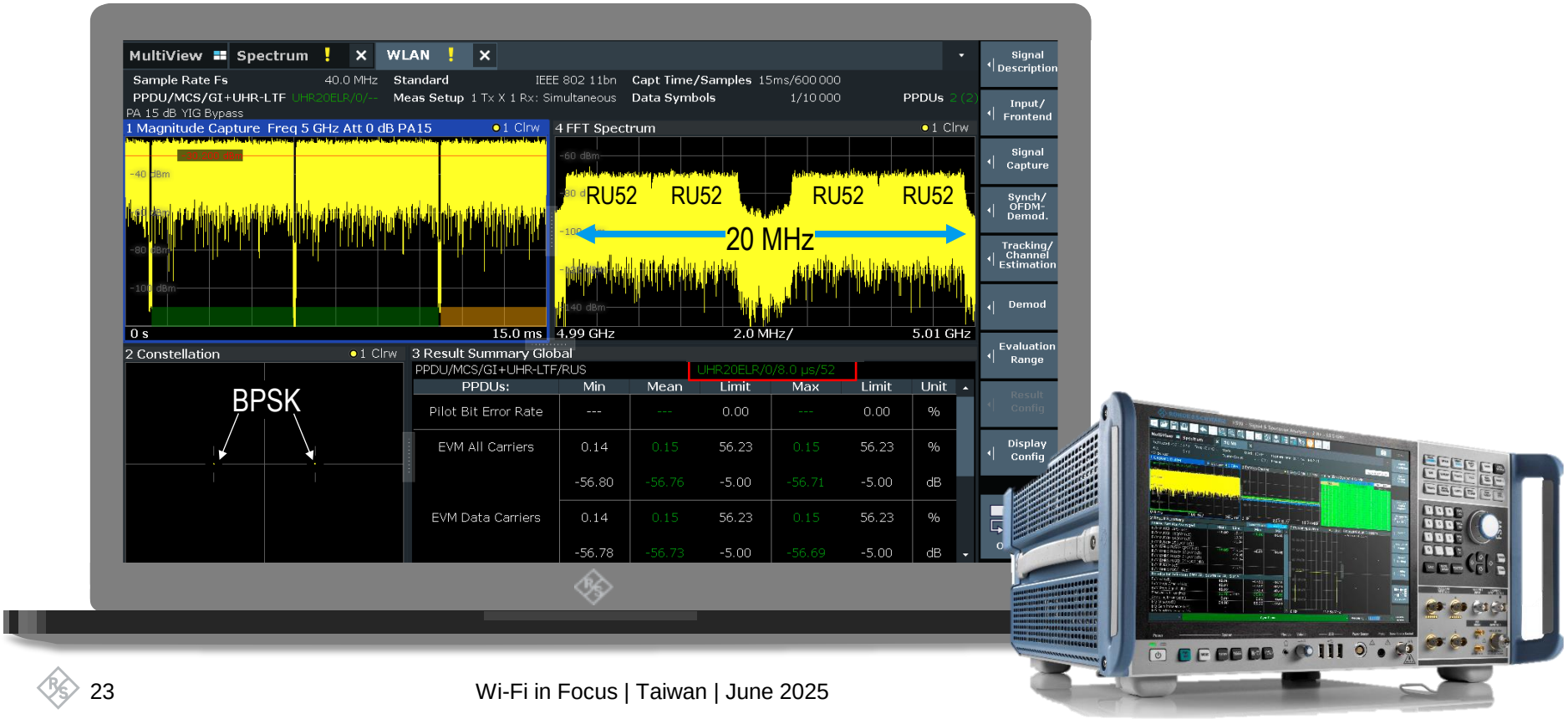
ELR could improve link budget by 6 dB and would apply to
- DL and UL in 2.4GHz and
- UL only in 5/6 GHz bands

The bandwidth of ELR PPDU is 20MHz and one spatial stream is used for ELR transmission only

ELR used four times frequency domain repetition over 52-tone regular RUs in 20 MHz

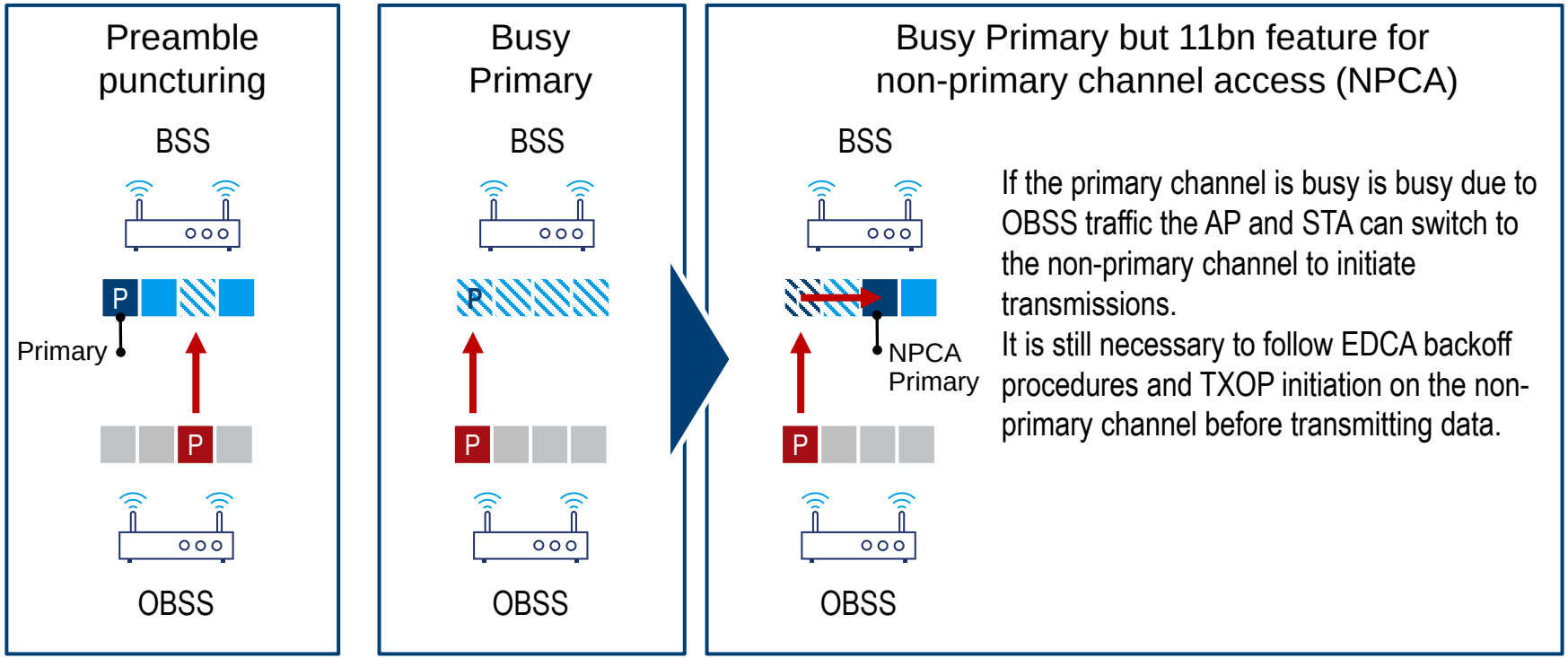
ELR PPDU MCS support:
UHR-MCS0: BPSK, R=1/2
UHR-MCS1: QPSK, R=1/2

UHR Extended Range PDDU automatically detected and analyzed by R&S®FSW



Non-primary channel access (NPCA)

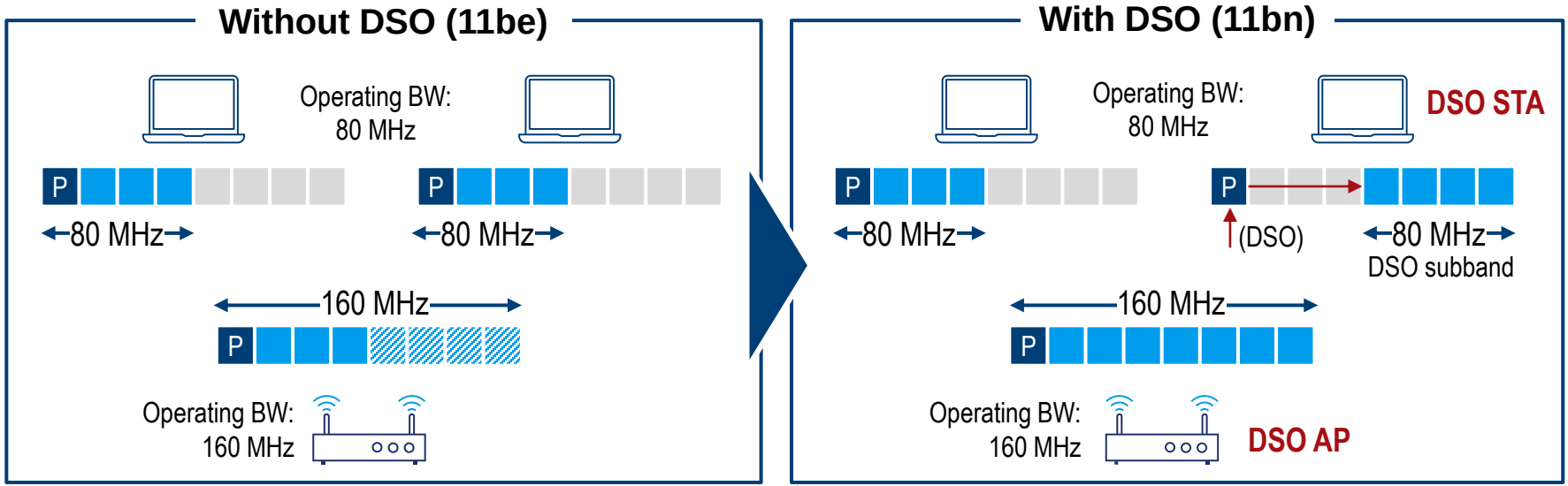
Mitigate congestion and improve spectrum efficiency in case of busy primary channel due to OBSS traffic



Dynamic subband operation (DSO)

More efficient use of spectrum in case of non-AP STAs with narrower bandwidth than BSS operating bandwidth

Dynamic subband operation (DSO) is a mechanism where **narrower bandwidth DSO STA (80 or 160 MHz)** can dynamically, on a per-TXOP basis, be allocated resources **outside of its current operating bandwidth** within the DSO AP's BSS bandwidth.

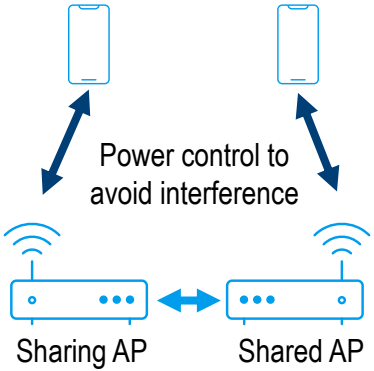


Multi Access Point Coordination

An new multi access point coordination framework

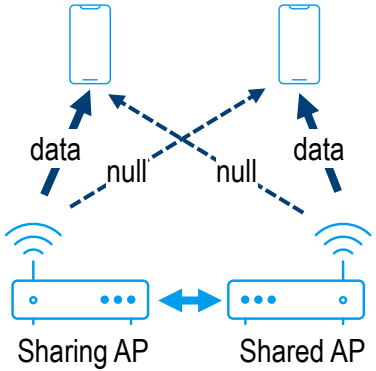
Spatial Reuse (Co-SR)

at TxOP level with power control



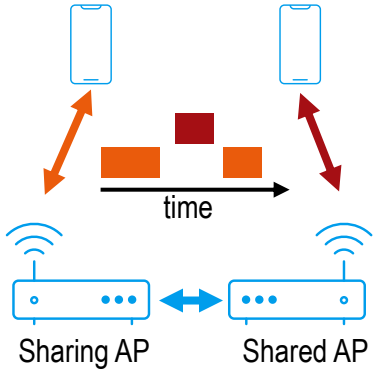
Beam Forming (Co-BF)

focus transmission towards user while nulling interference



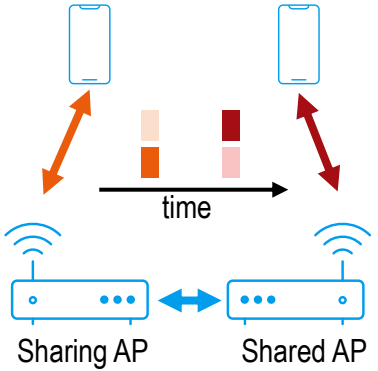
Transmission (Co-TDMA)

AP to share its time resources of to avoid medium contention



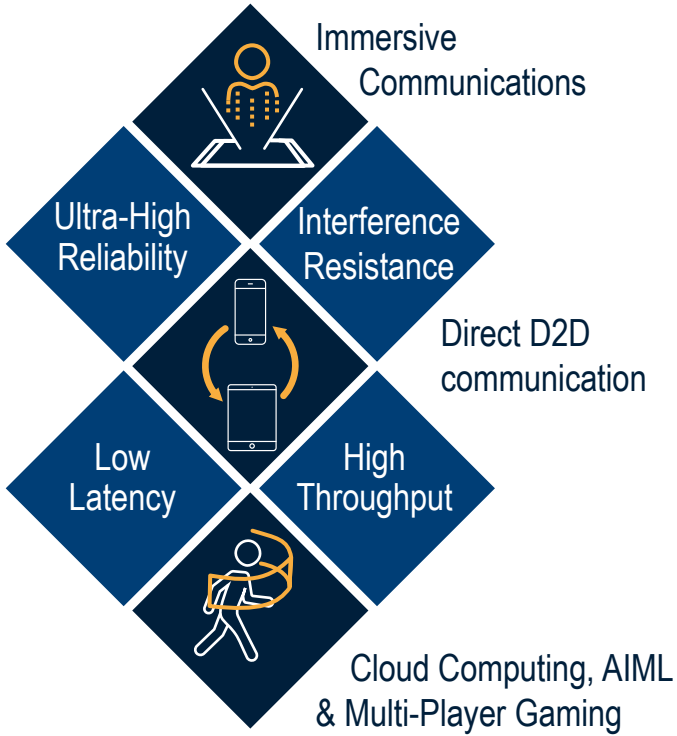
Restricted TWT (Co-RTWT)

coordinate their rTWT schedule(s) and/or to protect rTWT of other APs

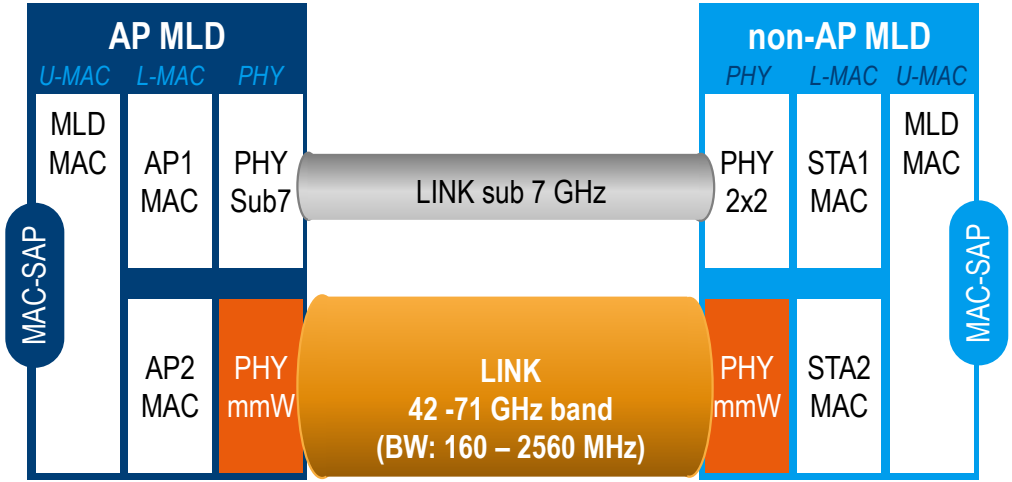


Integrated mmWave

Wi-Fi goes (again) mmWave with integrated mmWave (ImmW) specified in new TGbq



Only in MLO operation with at least on sub 7GHz link



- non-overlapping channels 42-71 GHz using single-user OFDM
- leverages or reuses existing PHY and MAC (11be) specifications defined for the operation in sub-7 and MLO
- single-user (SU) OFDM, single stream, 2.5 MHz SCS, up to 256QAM

Other topics of high interrest

WLAN sensing
802.11bf

WLAN sensing is the use of PHY and MAC features of IEEE 802.11 stations to obtain measurements that may be useful to estimate features of objects in an area of interest.

WG approval (March 2025)

320 MHz ranging
802.11bk

320 MHz positioning will enhance the IEEE 802.11 fine time measurements (FTM) positioning protocols with the IEEE 802.11be derived 320MHz waveforms.

Draft 5.0 (March 2025)

Ambient power
802.11bp

Enable the operation of an Ambient Power Comm. (AMP) station that is powered using energy harvesting incl a mode of wireless power transfer in the sub-1 GHz band

Draft 0.1 (June 2025)

AIML Studies

Studies about meaningful uses for AIML for example for performance improvement via smart parameter selection or reduced CSI feedback etc-

Report drafts (March 2025)

x

The ultimate goal: provide an immersive and interactive user experience in homes, offices, factories, and on the go.

Wi-Fi

Low power

Haptic feedback

Motion tracking

Ultra low latency

Reliable

FEEL

SEE

HEAR

Spherical view

Stereoscopic displays

Extreme high data rate

Thermal comfort

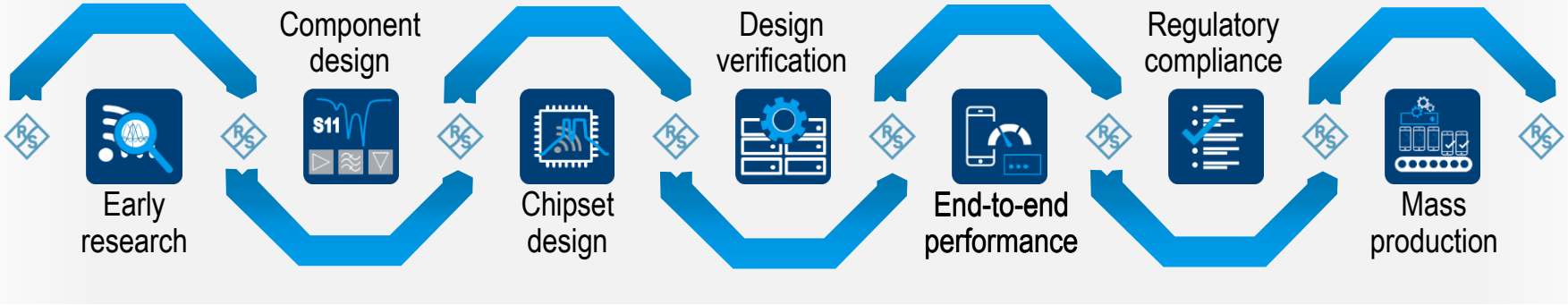
High res. audio

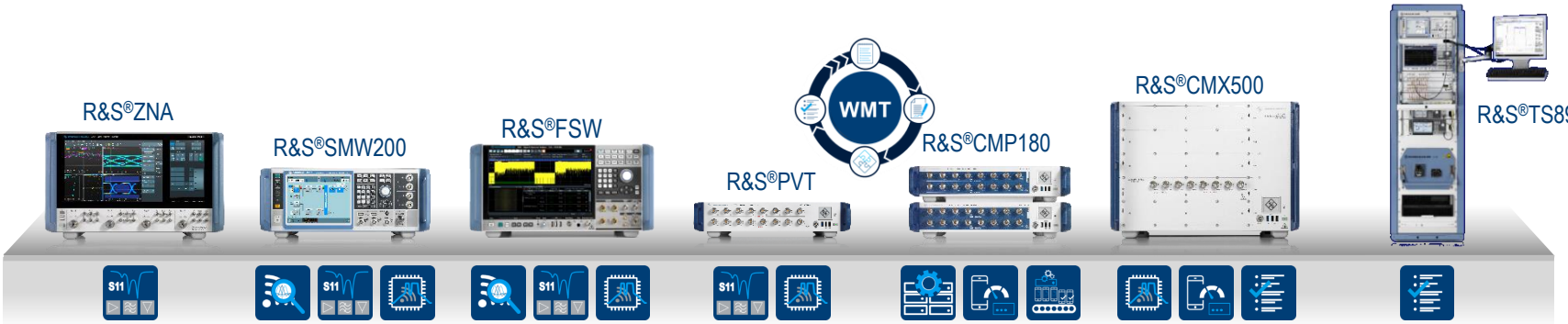
3D audio

Synchronous streams

5G NR

We continuously enhance our wireless testing portfolio to empower the ecosystem at the forefront of innovation.



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谢谢
THANK YOU
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