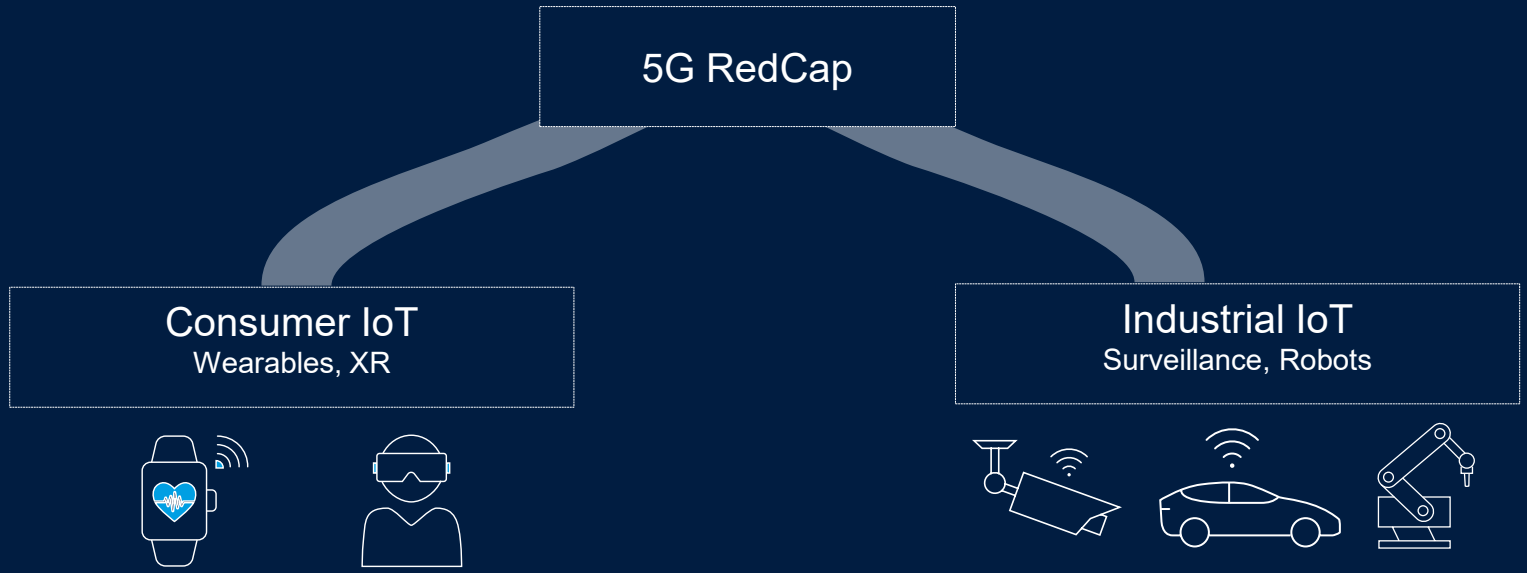
Wireless Communications

OVERVIEW OF REDCAP, eREDCAP IN 5G NR

Debasis Ratha
Principal Technical Trainer – Cellular Technology

ROHDE&SCHWARZ
Make ideas real

5G REDCAP MAIN USE CASES



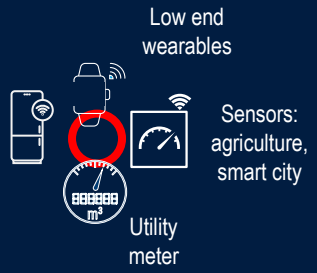
5G DEVICE EXPANSION WITH REDCAP

high

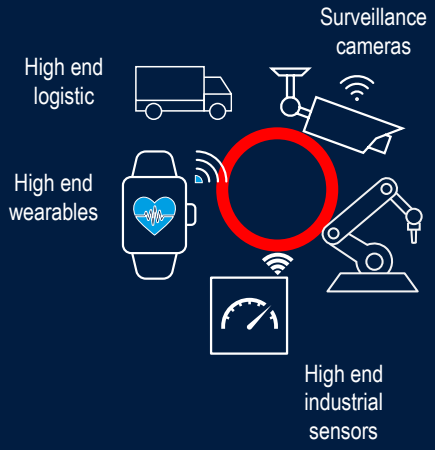
Device complexity

low

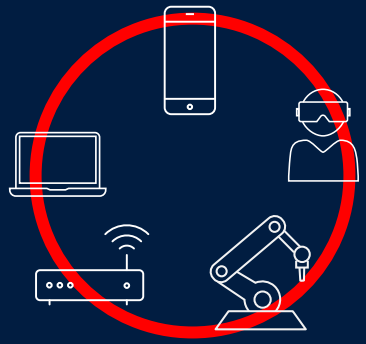
eMTC/NB-IoT
Lowest complexity
and delay tolerance



RedCap
Lower complexity
and power



eMBB/URLLC
Highest performance

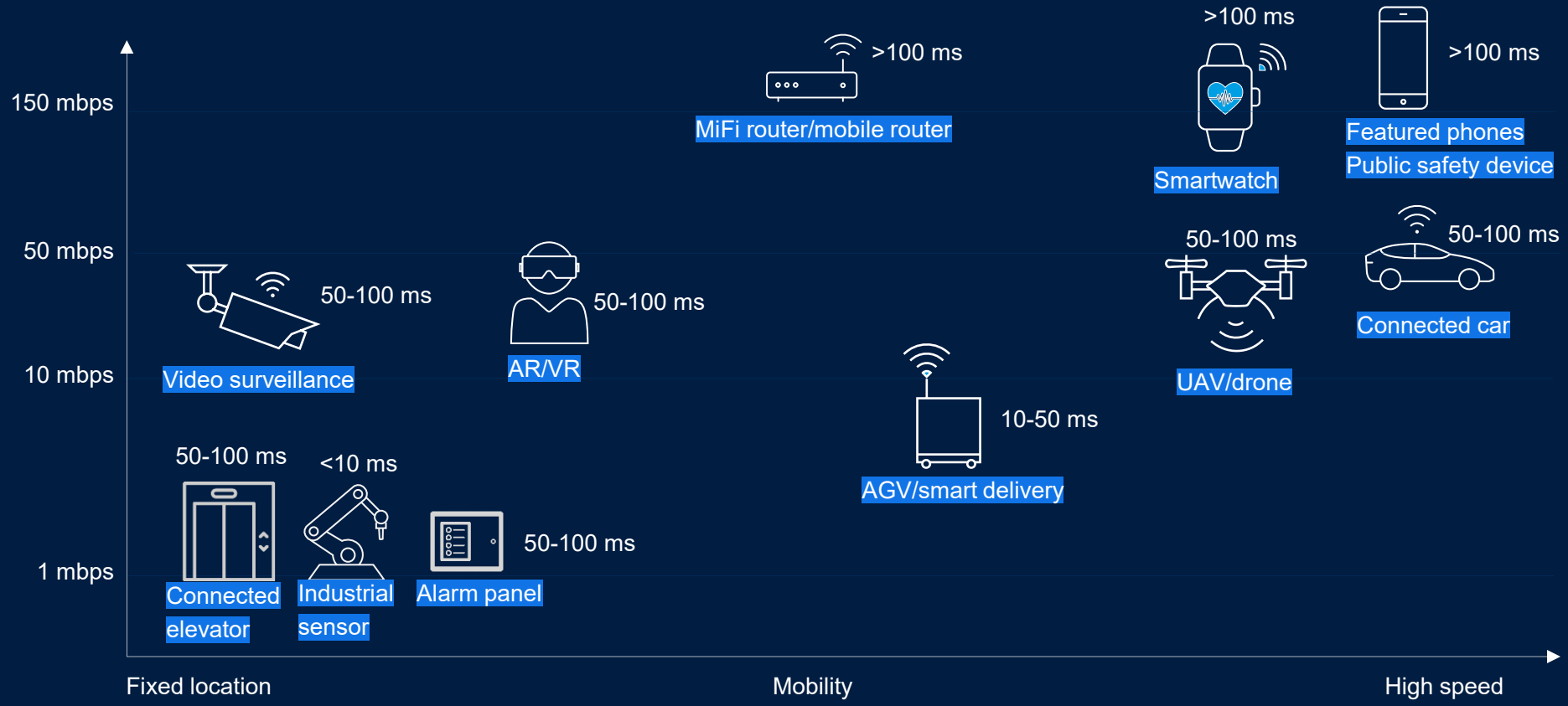


*size of bubble indicates device cost

Device performance

high

5G DEVICE EXPANSION WITH REDCAP CONTD.



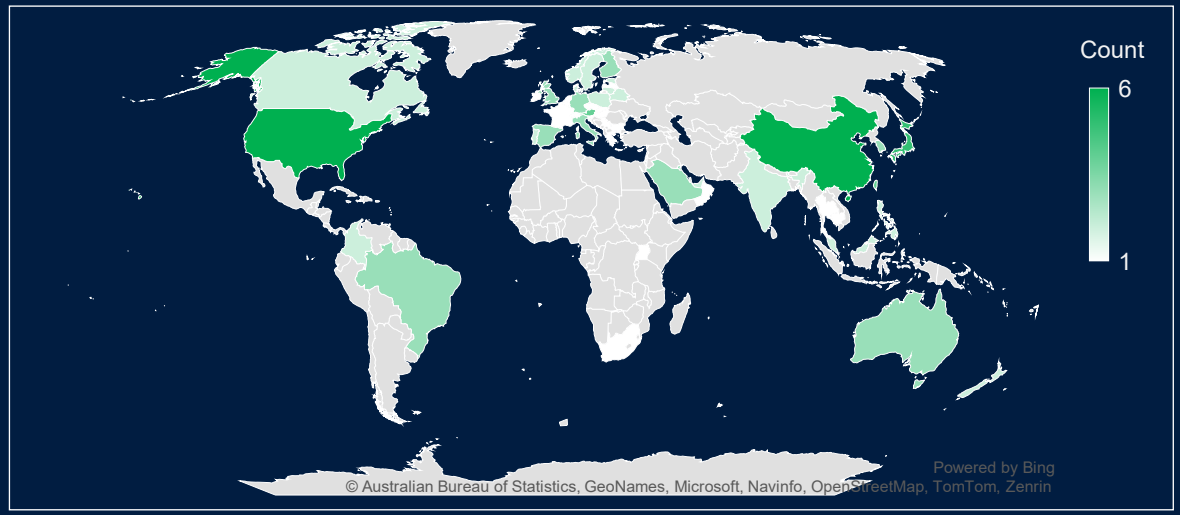
REDCAP DEVICE WORKS ONLY OVER 5G SA NW

532
5G Operators
out of which

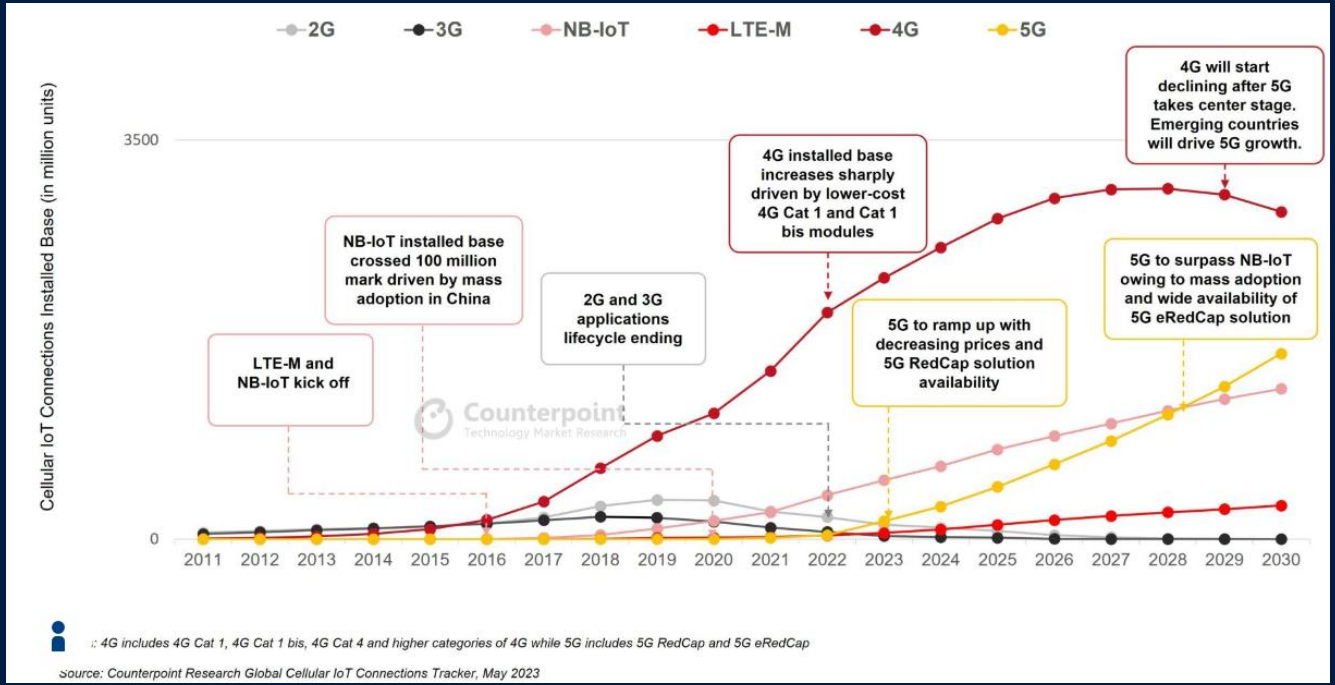
- Commercial **254**
  - 5G SA **41**
    - mmW **59**
    - 5G FWA **109**
- Investing **278**
  - Deploying SA **75**
  - 5G FWA investing **45**
- 5G private **1148**
  Deploying/trialing/investing

4G: 2,500

Global status of 5G SA deployments (41 launched, 75 deploying investing)



Cellular IoT Connections Installed Base



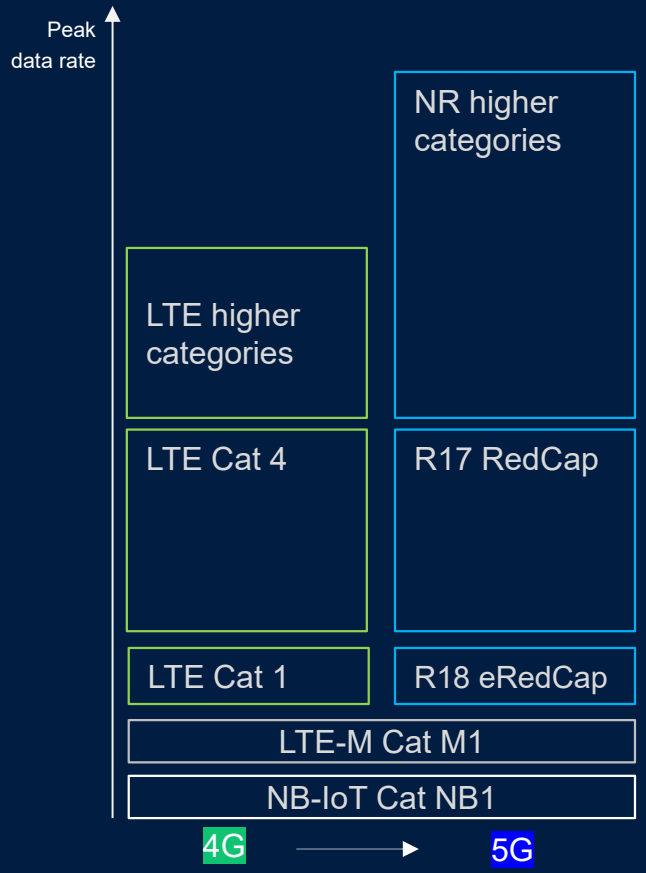
The global cellular IoT connections installed base is expected to surpass 6 billion by 2030 with a CAGR of 10.8%. The growth will be mainly driven by cellular connectivity adoption across various sectors such as utilities, automotive, industrial, retail and healthcare.

Unlike the previous decade, where consumer devices like smartphones and PCs played a significant role in driving cellular connections, this decade will see a shift towards cellular connections propelled by the digital transformation initiatives undertaken by enterprise IoT payers.

Highlights of cellular IoT connections installed base:

- Global cellular IoT connections grew 29% YoY to reach 2.7 billion in 2022 with 4G continuing to grow its majority share.
- China held over two-thirds of cellular IoT connections in 2022, followed by Europe and North America.
- NB-IoT dominates in China, while LTE-M is preferred in Australia, Japan and North America; Europe supports both.
- 4G and NB-IoT are the most preferred cellular IoT applications technologies.
- 5G is nascent as module prices and breadth of applications reflect early-stage dynamics.
- IoT growth drivers are shifting, with the enterprise and transformation initiatives key in propelling IoT connections forward.

CELLULAR IoT EVOLUTION



Features		5G NR	5G RedCap (1T2R)	5G RedCap (1T1R)	Cat 4	Cat 1/Cat 1bis
Throughput		UL: 145 Mbps	UL: 50 Mbps	UL: 50 Mbps	UL: 50 Mbps	UL: 5 Mbps @16QAM
	FDD	DL: 290 Mbps @256QAM/2T4R/50M	DL: 150 Mbps @64QAM/1T2R	DL: 85 Mbps @64QAM/1T1R	DL: 150 Mbps @64QAM/1T2R	DL: 10 Mbps @64QAM/1T1R
		UL: 250 Mbps	UL: 22 Mbps	UL: 22 Mbps	UL: 15 Mbps	UL: 1 Mbps @16QAM
	TDD	DL: 1.7 Gbps @256QAM/2T4R/100M	DL: 124 Mbps @64QAM/1T2R	DL: 62 Mbps @64QAM/1T1R	DL: 110 Mbps @64QAM/1T2R	DL: 7.4 Mbps @64QAM/1T1R
URLLC		1 ms support URLLC	5~10 ms@99.99% support URLLC	5~10 ms@99.99% support URLLC	>100 ms	>100 ms
Power consumption		100 mA~3 A	Working: 120~160 mA Idle:12~22 mA	Working: 120~160 mA Idle:12~22 mA	Working: 120~160 mA Idle:12~22 mA	<100 mA
Network slicing		✓	✓	✓	✗	✗
5G LAN		✓	✓	✓	✗	✗
Voice		VoNR	VoNR	VoNR	VoLTE	VoLTE
Mobility		✓	✓	✓	✓	✓
NTN		✓	Discussed	Discussed	✗	✗
Chipset/modem cost		$80-$150	$20-$40	$5-$20	$5-$10	$1-$5

DEVICE OPTIMIZATION

MR-DC: Multi-RAT Dual Connectivity
DAPS: Dual Active Protocol Stack
CPAC: Conditional PSCell Addition or Change
IAB: Integrated Access Backhaul

FR1 max. BW 20 MHz
DL: 256QAM optional

FR2 max. BW 100 MHz

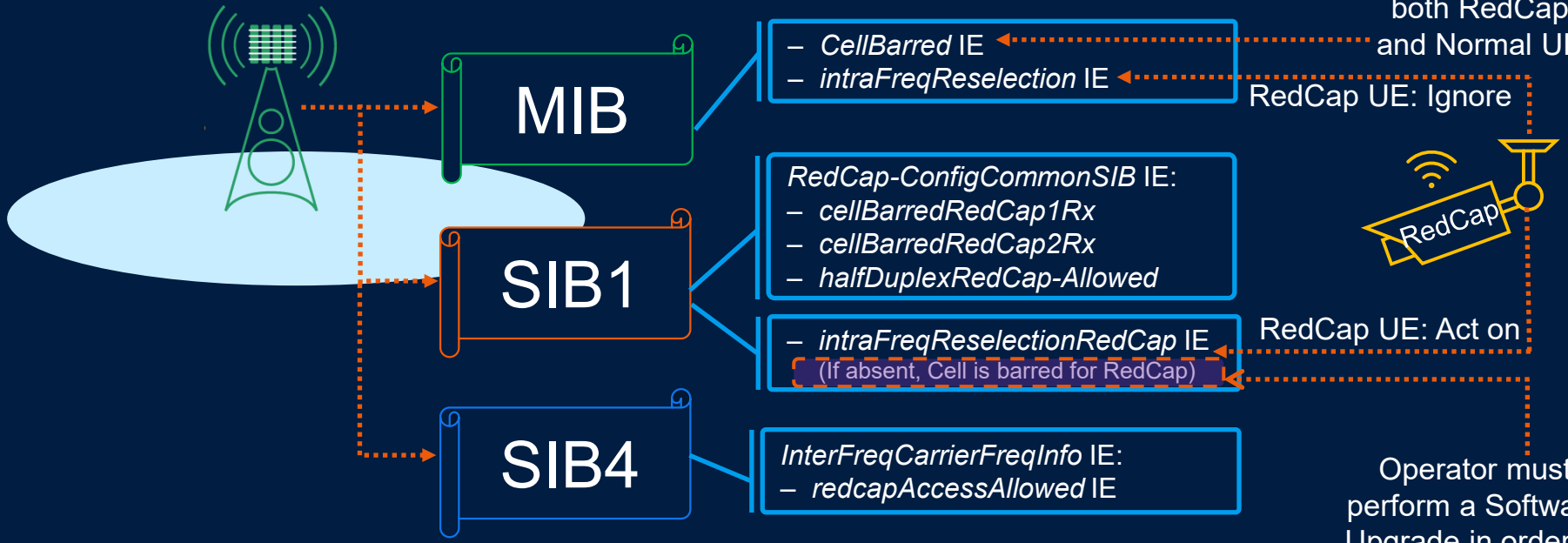
FR1 and FR2

- Half duplex FDD type A (full duplex optional)
- No support for: CA, MR-DC, DAPS, CPAC and IAB → **only NR-SA**

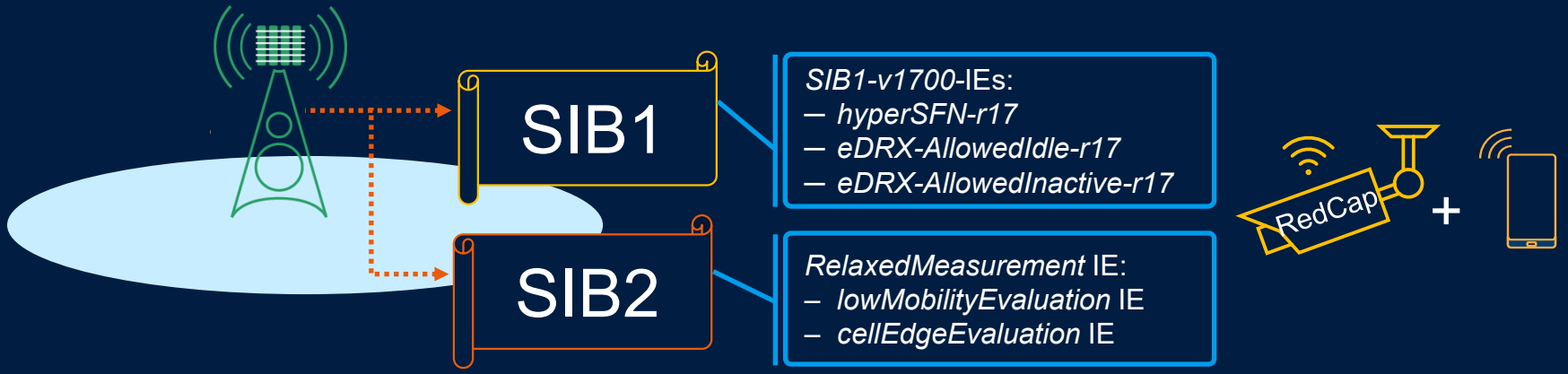
RedCap Device – Optimized Features in R17

Bandwidth reduction	Max bandwidth: 20 MHz (FR1), 100 MHz (FR2)
Number of UE RX antennas	1 or 2 RX antennas (FR1), 2 RX antennas (FR2)
Number of UE TX antennas	Single TX antenna
Optional support for higher order modulation schemes	Max modulation: 64QAM
Half-duplex operation	Half-duplex mode
Reduced capabilities for mobility scenarios and multicarrier operations	No CA, MR-DC, DAPS, CPAC, IAB
Early RedCap UE identification by the network	Early RedCap support indication
UE capability specific network access restrictions	Access restrictions for certain UE capabilities
RRM measurement relaxation	Relaxation of RRM measurements
Bandwidth part (BWP) operation	UE-specific or RedCap-specific BWP
Reduced number of data bearers (DRB)	Max 8 DRBs to achieve the desired throughput
Shorter RLC and PDCP sequence number	12 bit RLC/PDCP sequence number, saving memory
PC3	Transmit power	Power class 3, extensions for FR2
✕	PUCCH frequency hopping disabled	Reduce uplink resource fragmentation
Fewer frequency bands	Assumed fewer bands for reduced complexity

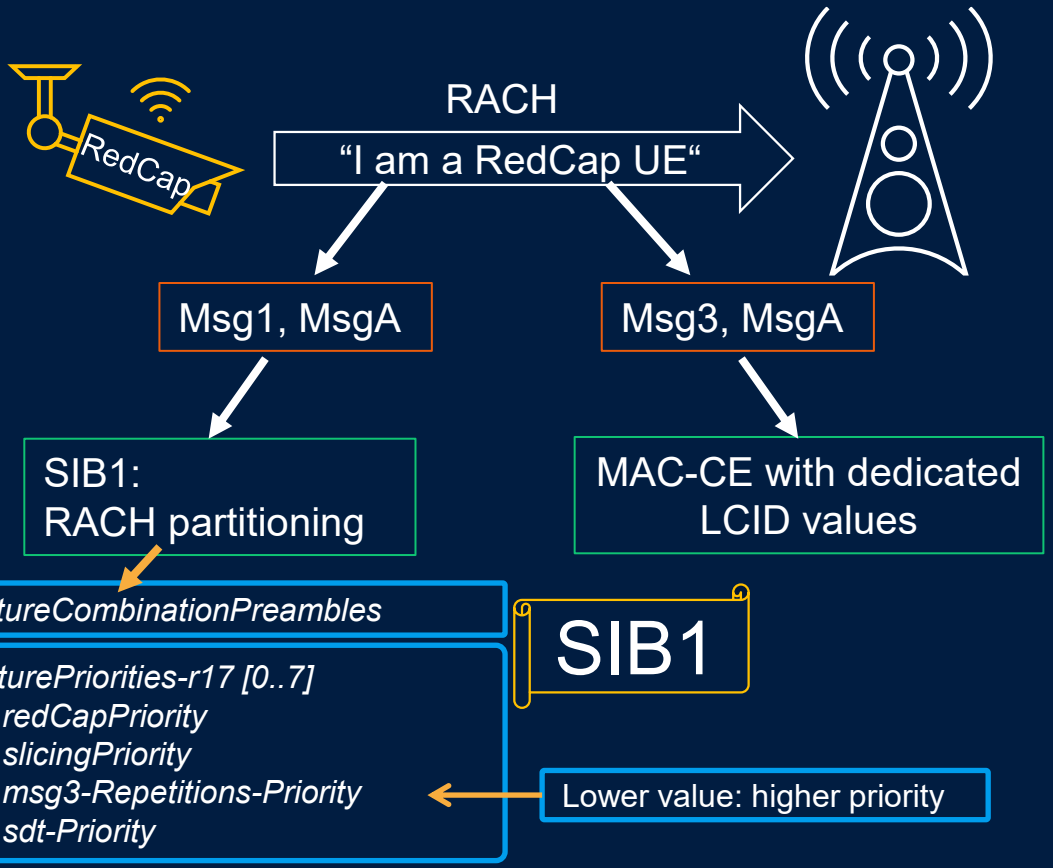
5G NR REDCAP: SYSTEM INFORMATION FOR CELL ACCESS CONTROL

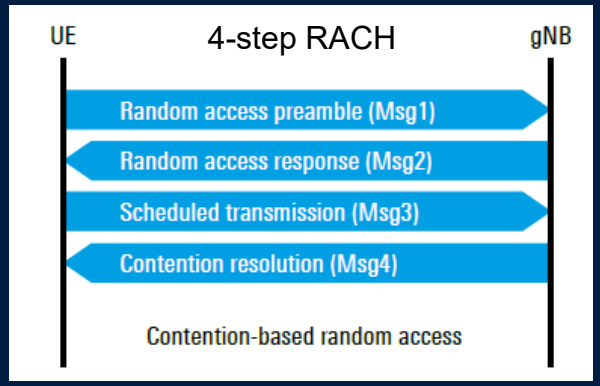


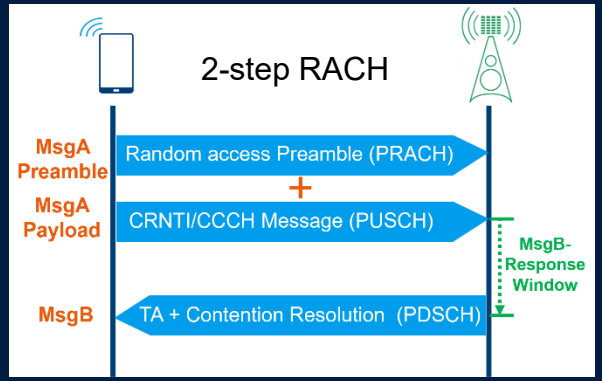
5G NR REDCAP: SYSTEM INFORMATION FOR POWER SAVING IN IDLE MODE



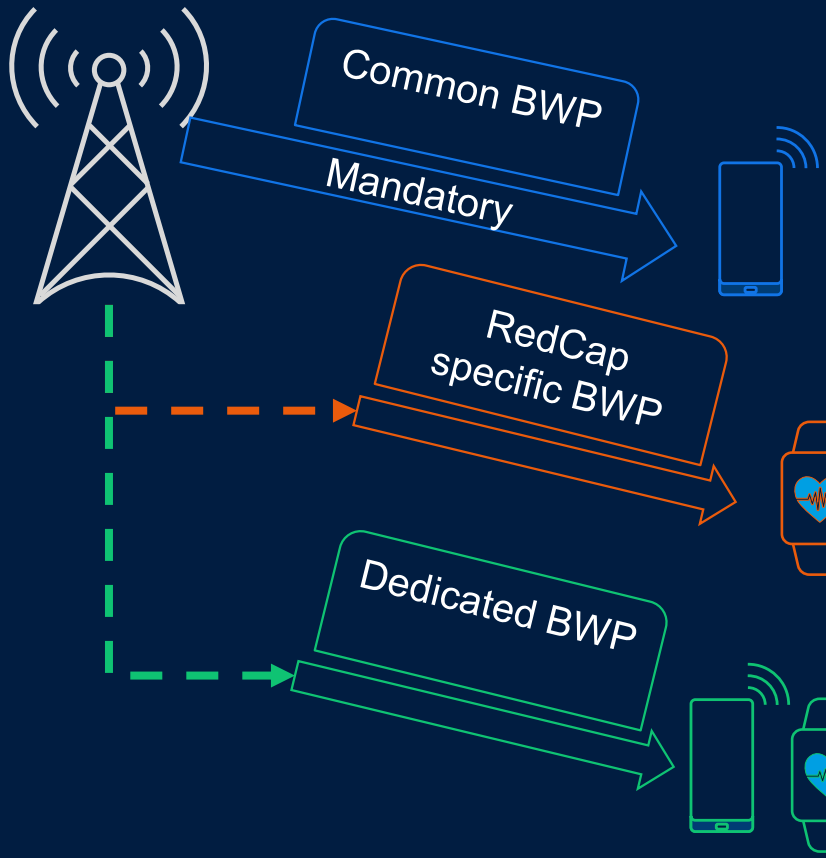
5G NR REDCAP: EARLY INDICATION







5G NR REDCAP: Bandwidth Parts (BWP)



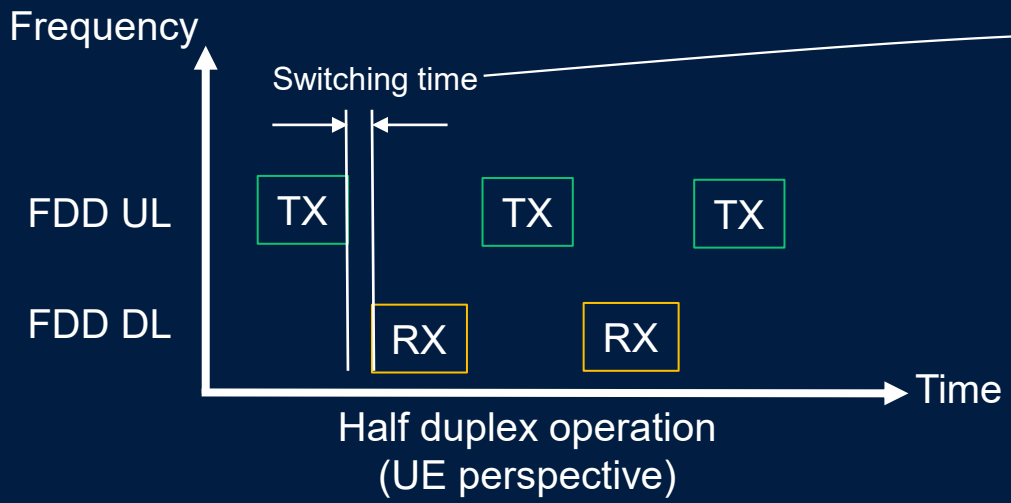
Network schedules a BWP common for all UEs. Drawback is that this BWP is not allowed to be larger than the UE capability (e.g. RedCap UE has no access)!

Optionally, the network schedules a BWP specific for RedCap UEs. Drawback: This BWP needs to cover the UE bandwidth, otherwise cell is considered as “barred“.

Optionally, the network may configure a dedicated DL BWP (either way RedCap or non-RedCap UEs) => higher flexibility to adjust BWP to UE needs.

5G NR REDCAP: HD-FDD Operation

- Although a FDD band is used, a HD-FDD UE can not send and receive at the same time
  → gNB should take care, but collisions still may occur
  → collision handling rules required → 38.213 17.2



Transition time	FR1	FR2
N_{RX-TX}	25600	13792
N_{TX-RX}	25600	13792

Time = $N*T_C$ 38.211

NEW POWER CLASS FOR SPECIFIC FR2 BANDS

Power Class	Typical Use Case	Minimum Peak EIRP (approx.)
1	Fixed Wireless Access (FWAs)	40dBm(n257, n258)
2	Vehicular UEs	29dBm
3	Handheld UEs	22.4-30.40dBm(band-dependent)
4	High-Power Non-Handheld UEs	34dBm(n257, n258, n261)
5	FWA UEs with lower power output	30.0-30.40dBm(band-dependent)
6	High-Speed train roof mounted UEs	30dBm(n257, n261)
7	RedCap UEs	16.4dBm(n257, n258, n261)

ENHANCED REDCAP (eREDCAP, Relase-18)

eRedCap Device – Optimized Features in R18

Bandwidth reduction to 5 MHz	Max bandwidth: 5 MHz (FR1), enables ~10 Mbps peak data rate
Future railway mobile communications system (FRMCS)	5G-based railway communications system, co-existence with GSM-R
RedCap for mission critical communications (MCX)	Support for direct device to device communications, possible 3 MHz bandwidth UE in NR band n28
RedCap sidelink support	Combines RedCap and NR-V2X features, includes operation on narrow bandwidth, power saving methodologies
RedCap enhancements for narrowband positioning	RedCap-optimized positioning methodologies, includes PRS transmission in narrow bandwidth, time of arrival measurements
Study on further RedCap complexity reduction	Additional complexity reduction techniques, UE processing relaxation, BWP operation with or without SSB and RF retuning

RedCap evolution	5G eMBB	Rel. 17	Rel. 18
Bandwidth	100 MHz	20 MHz	5 MHz
Peak rate	2 Gbps	100 Mbps	10 Mbps
Cost assessment	100%	-60%	-71%

eREDCAP : 5MHz MAXIMUM BASEBAND BANDWIDTH

RF BW: 20MHz Max; BB BW: 5MHz Max (25 PRBs with 15kHz SCS, 12 PRBs with 30kHz SCS) - OPTIONAL

Downlink

RF Bandwidth (Max: 20MHz)

BB Bandwidth (Max: 5MHz)

Contiguous Allocation

Downlink

RF Bandwidth (Max: 20MHz)

BB BW: N_4 PRBs

BB BW: N_3 PRBs

BB BW: N_2 PRBs

BB BW: N_1 PRBs

$N_1 + N_2 + N_3 + N_4 \leq 25/12$

15kHz SCS

30kHz SCS

Non-Contiguous Allocation

Uplink

RF Bandwidth (Max: 20MHz)

Non-Contiguous allocation in UL is not allowed

BB Bandwidth (Max: 5MHz)

Non-Hopping Allocation

Uplink

RF Bandwidth (Max: 20MHz)

BB BW: N PRBs

BB BW: N PRBs

BB BW: N PRBs

BB BW: N PRBs

Per Slot Per Hop

$N \leq 25/12$

15kHz SCS

30kHz SCS

Intra-Slot Hopping Allocation

eREDCAP : BASEBAND BANDWIDTH FOR BROADCAST MSG

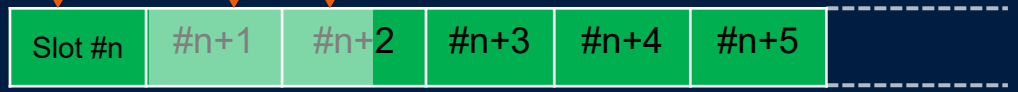
SIs, Paging and Msg2 are allowed to be sent with more than 25(15kHz SCS)/12(30kHz SCS) PRBs, but with Relaxed Timeline for following scheduling

Reasoning: Since these broadcast type messages are sent for all different UEs, introducing restrictions specifically for eRedCap UEs will bring in additional complexities

SI/Paging/Msg2

BB Bandwidth (> 5MHz)

Network takes care of not scheduling eRedCap UE



UE decoding Bandwidth (Max: 5MHz)

UE post-FFT buffer size is not less than 20MHz

eREDCAP: TIMELINE RELAXATION FOR MSG3

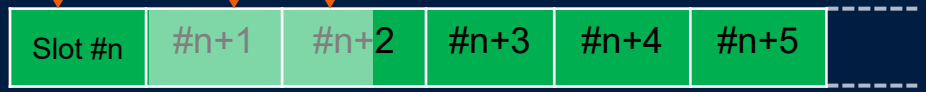
Msg2 ≤ 25(15kHz SCS)/12(30kHz SCS) PRBs: Gap between Msg2 & Msg3 must be ≥ ($N_{T,1}$+ $N_{T,12}$+0.5ms) → Same as Legacy UEs

Msg2 > 25(15kHz SCS)/12(30kHz SCS) PRBs: Gap between Msg2 & Msg3 must be ≥ ($N_{T,1}$+ $N_{T,12}$+ 0.5ms + **X**) → X = 1 Slot (1ms/0.5ms)

Also, Network must take care of not allocating Msg3 resource (in RAR or DCI) PRBs > 25(15kHz SCS)/12(30kHz SCS)

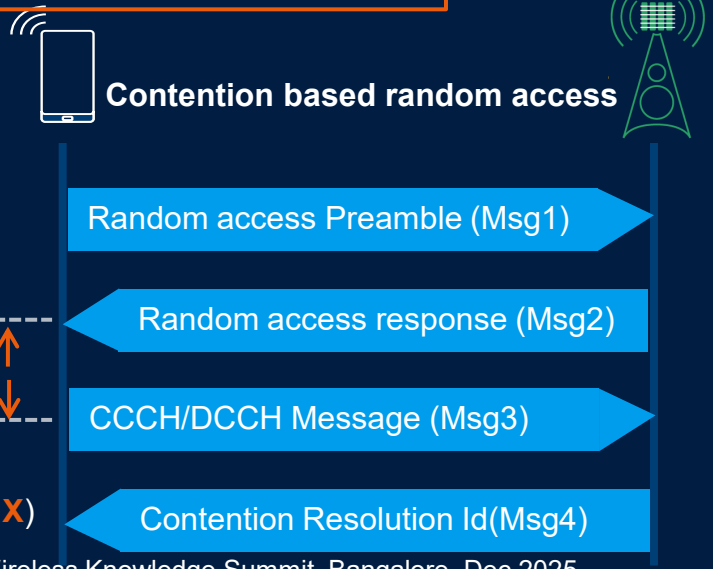
Msg2(RAR) BB Bandwidth (> 5MHz)

Network takes care of not scheduling **Msg3** for eRedCap UE



UE decoding Bandwidth (Max: 5MHz)

RAR > 25/12 PRBs → ($N_{T,1}$+ $N_{T,12}$+ 0.5ms + **X**)

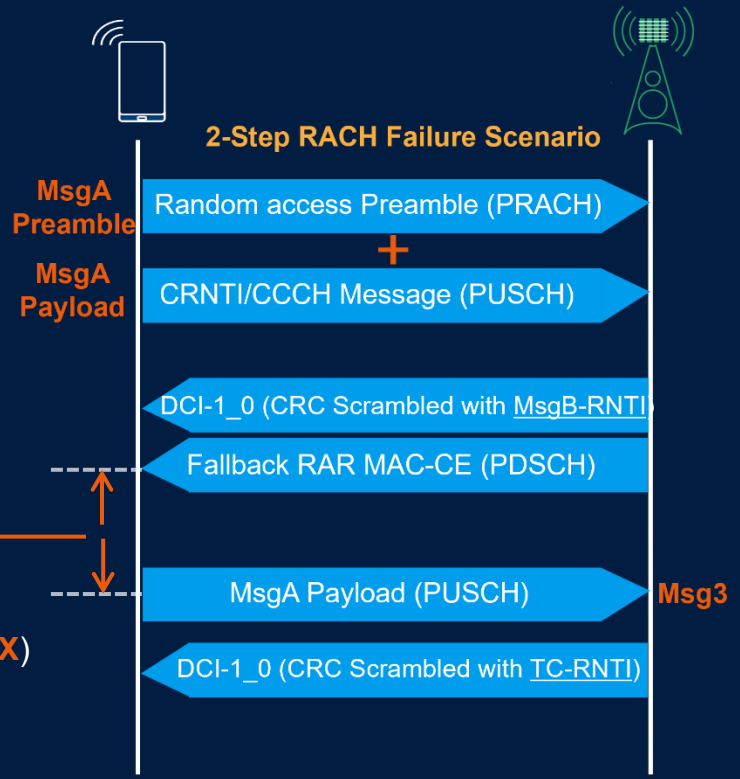


eREDCAP : TIMELINE RELAXATION FOR 2-STEP RACH

Fallback RAR > 25(15kHz SCS)/12(30kHz SCS) PRBs:
Gap between Msg2 & Msg3 must be ≥
$(N_{T,1} + N_{T,12} + 0.5ms + X)$ → X = 1 Slot (1ms/0.5ms)

All other cases with Timeline Relaxation in 2-Step RACH:

- Between reception of successRAR and transmission of corresponding HARQ-ACK
- Between unsuccessful reception of MsgB PDSCH and transmission of Msg1/MsgA
- Between reception of MsgB PDSCH with non-matching RAPID and transmission of Msg1/MsgA



Fallback RAR > 25/12 PRBs → $(N_{T,1} + N_{T,12} + 0.5ms + X)$

eREDCAP : MAX 10MBPS PEAK THROUGHPUT

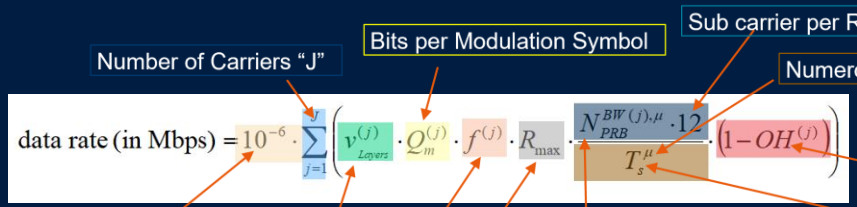
	5G eMBB	RedCap (R17)	eRedCap (R18)
Bandwidth	100 MHz	FR1: 20 MHz FR2: 100 MHz	FR1: 20MHz, with possible restriction to 5MHz occupation of the shared channels within this band FR2: not supported
Peak rate	2 Gbps	100 Mbps	10 Mbps

Normal & RedCap UE: $v_{Layers}.Qm.f \geq 4$

eRedCap UE with BB BW reduction: $v_{Layers}.Qm.f \geq 3.2$

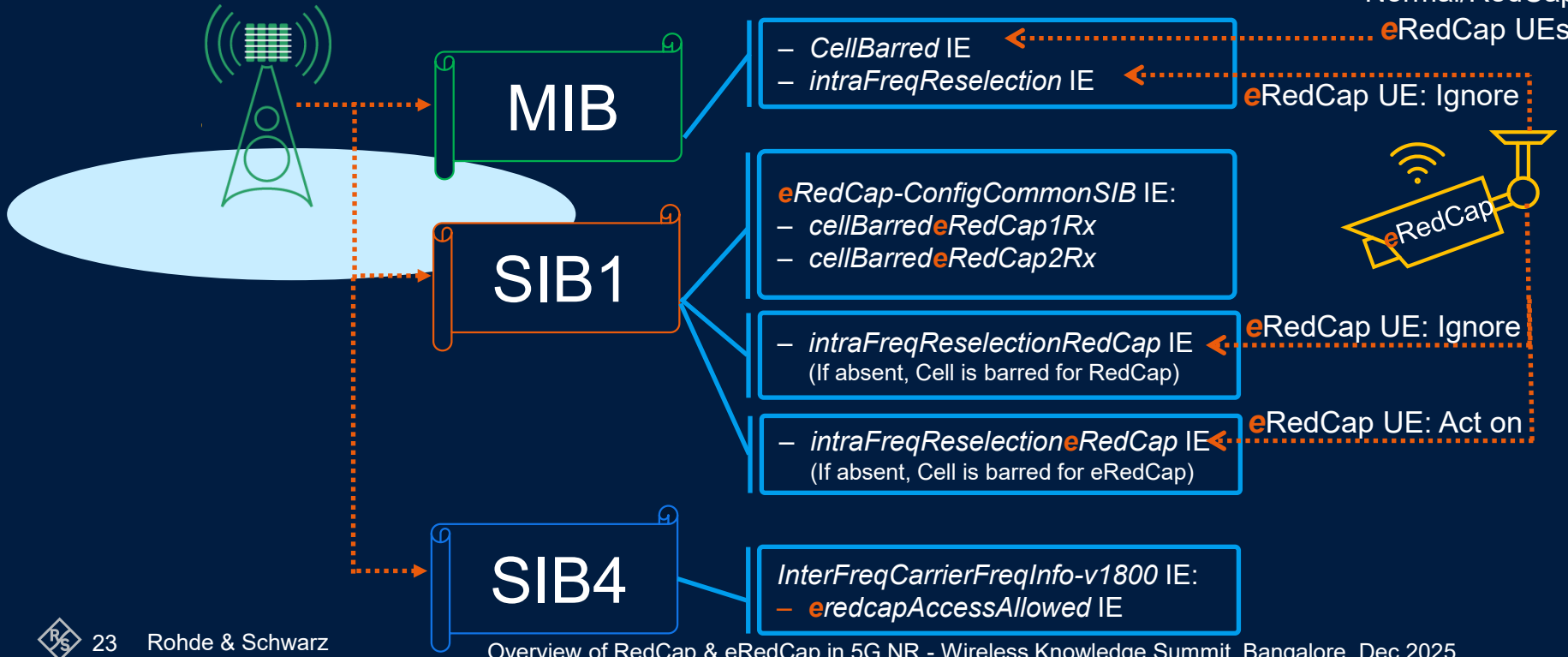
eRedCap UE without BB BW reduction and not supporting MIMO (v_{Layers} =1): $v_{Layers}.Qm.f \geq 0.75$

eRedCap UE without BB BW reduction and supporting MIMO (v_{Layers} =2): $v_{Layers}.Qm.f \geq 0.8$

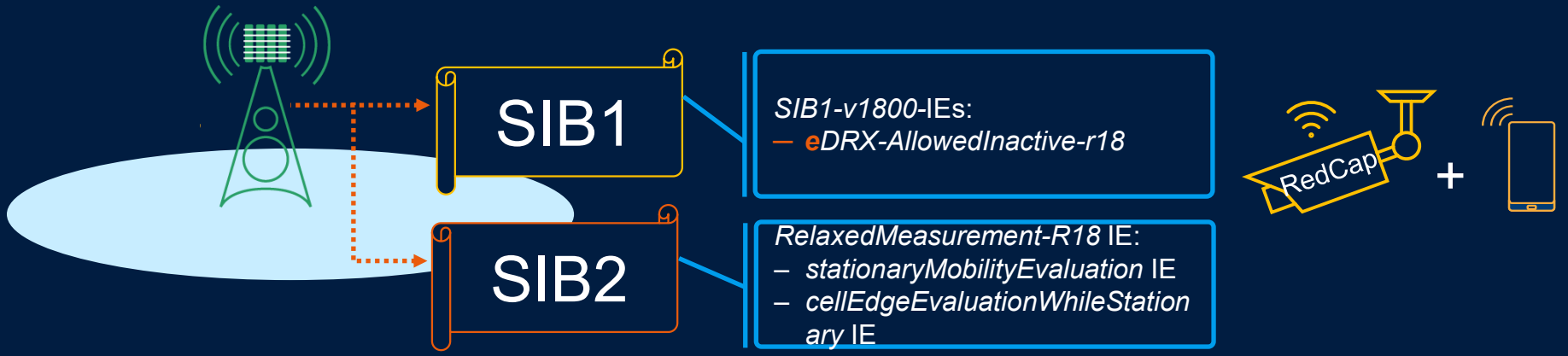


Source: 3GPP TS 38.306 V15.2.0 (2018-06)

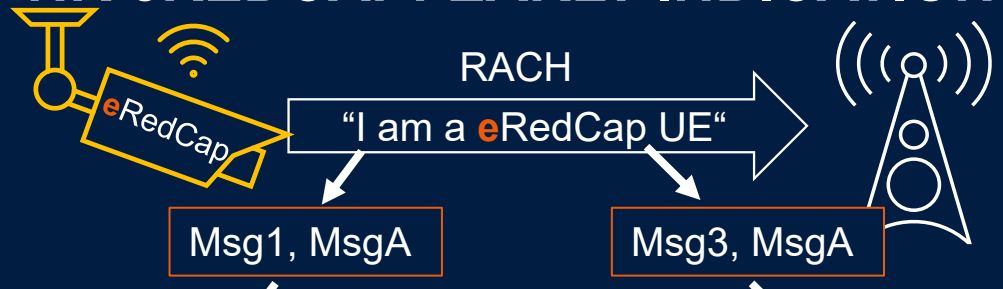
5G NR eREDCAP: SYSTEM INFORMATION FOR CELL ACCESS CONTROL



5G NR REDCAP: SYSTEM INFORMATION FOR POWER SAVING IN IDLE MODE



5G NR eREDCAP: EARLY INDICATION



SIB1:
RACH partitioning

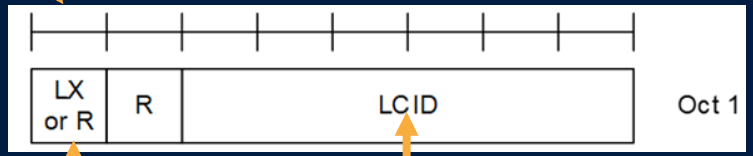
FeatureCombinationPreambles

FeaturePriorities-r17 [0..7]
- *redCapPriority*
- *slicingPriority*
- *msg3-Repetitions-Priority*
- *sdt-Priority*

FeaturePriorities-v1800 [0..7]
- *eRedCapPriority*
- *msg1-Repetitions-Priority*

SIB1

MAC-CE with dedicated LCID values



“LX” field set to ‘1’

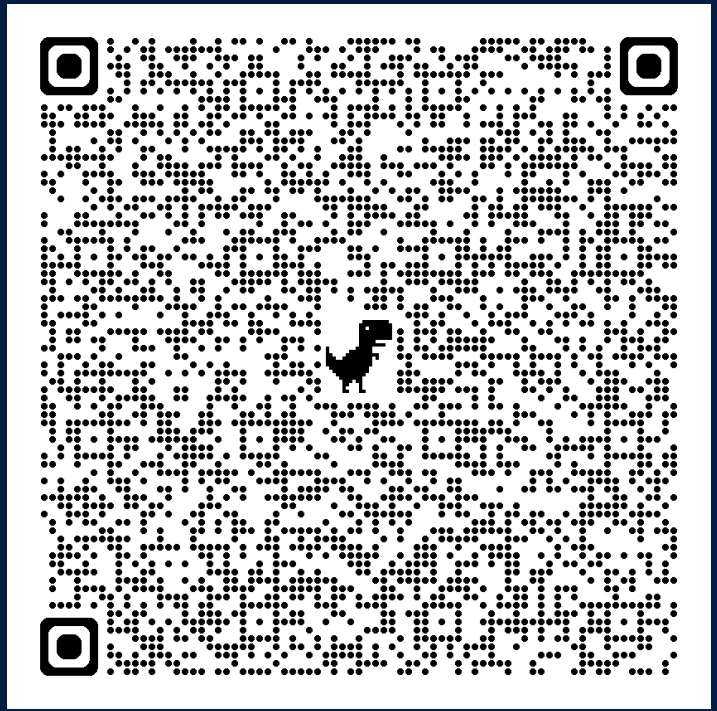
LCID Values 0-7 for different CCCH message size

Lower value: higher priority

POWER SAVING FEATURES: COMMON FOR ALL DEVICES

Power saving feature	Release
Wakeup signal (WUS) in connected mode DRX	Release-16
Cross slot scheduling with minimum K0/K2 offset	Release-16
RRM measurement relaxation in Idle/Inactive Mode (For low mobility scenario, cell edge scenario)	Release-16
Extended paging cycle in Idle Mode	Release-17
Paging Early Indication	Release-17
RRM measurement relaxation extensions in Idle/Inactive Mode (For low stationary mobility scenario)	Release-17
Small Data Transfer(SDT)	Release-17
Extended paging cycle in Inactive Mode	Release-18

WiFi 8 WHITE PAPER DOWNLOAD



Find out more

www.rohde-schwarz.com/redcap

THANK YOU

ROHDE&SCHWARZ

Make ideas real

Thank you

OVERVIEW OF REDCAP, eREDCAP IN 5G NR

ROHDE&SCHWARZ

Make ideas real