Wireless Communications

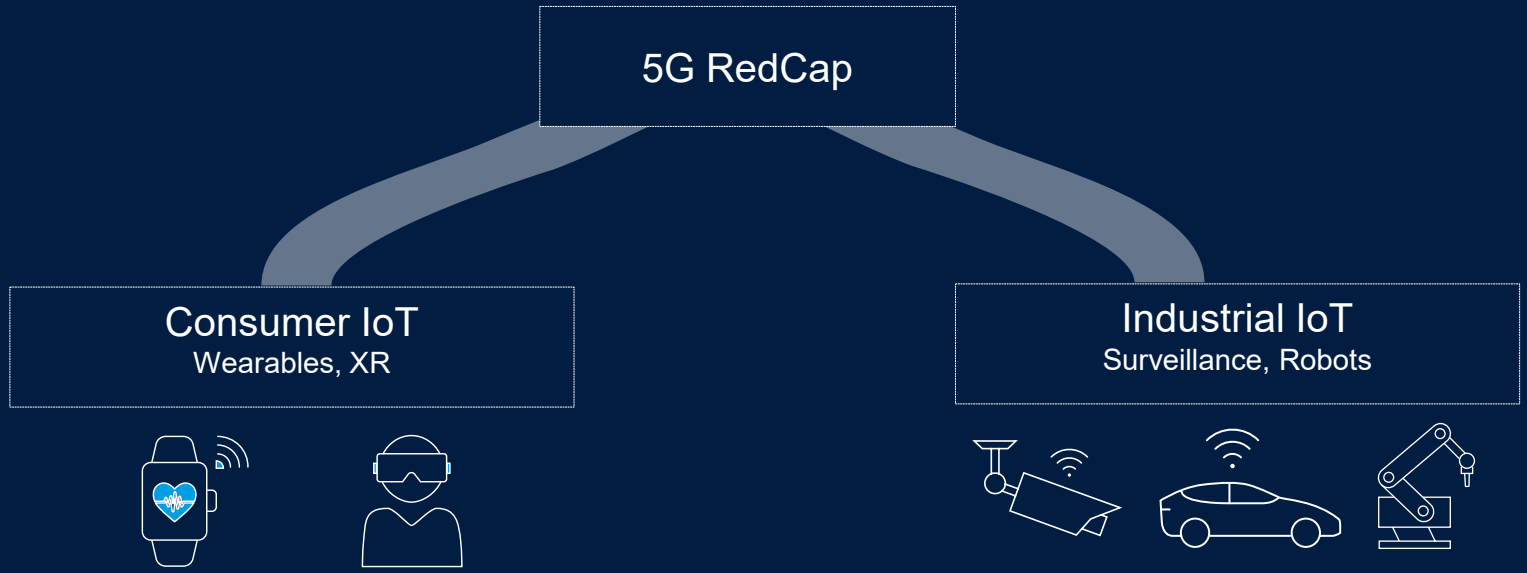
REDCAP DEVICE TESTING MADE EASY

Goce Talaganov
Market Segment Manager – Cellular Device

Manuel Galozy
Product Manager – Mobile Radio Tester

ROHDE&SCHWARZ
Make ideas real

5G REDCAP MAIN USE CASES



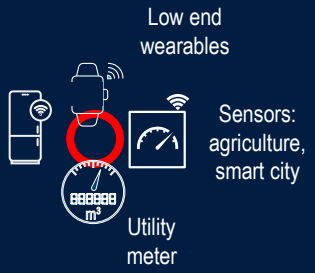
5G DEVICE EXPANSION WITH REDCAP

high

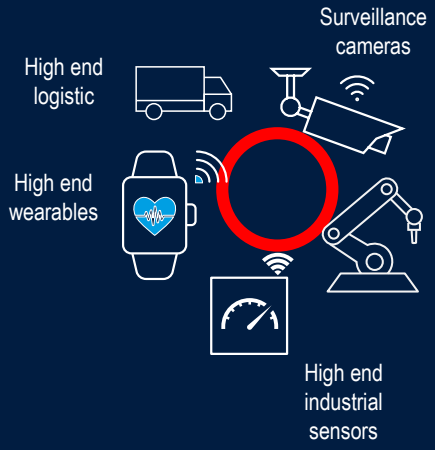
Device complexity

low

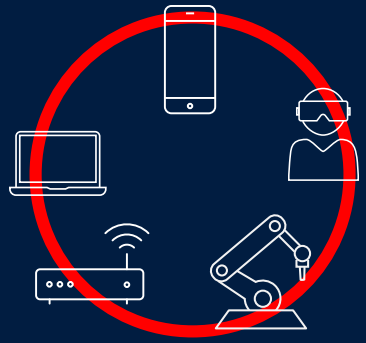
eMTC/NB-IoT
Lowest complexity
and delay tolerance



RedCap
Lower complexity
and power



eMBB/URLLC
Highest performance

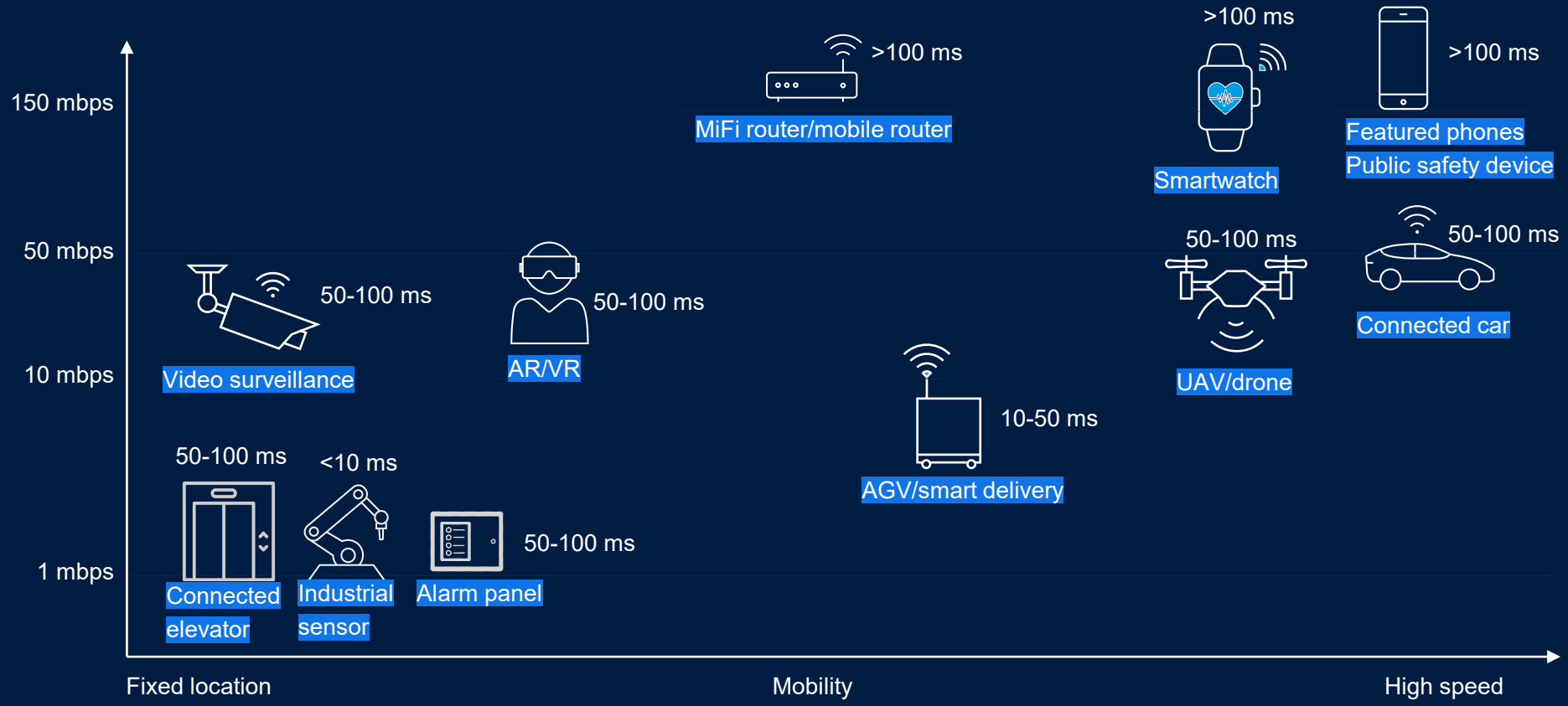


*size of bubble indicates device cost

Device performance

high

5G DEVICE EXPANSION WITH REDCAP CONTD.



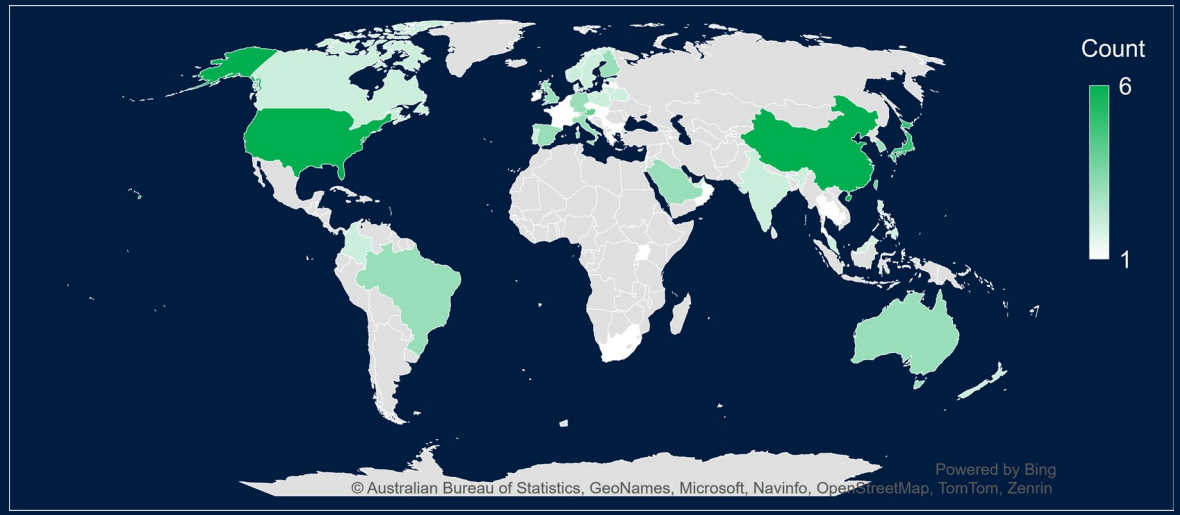
REDCAP DEVICE WORKS ONLY OVER 5G SA NW

532
5G Operators
out of which

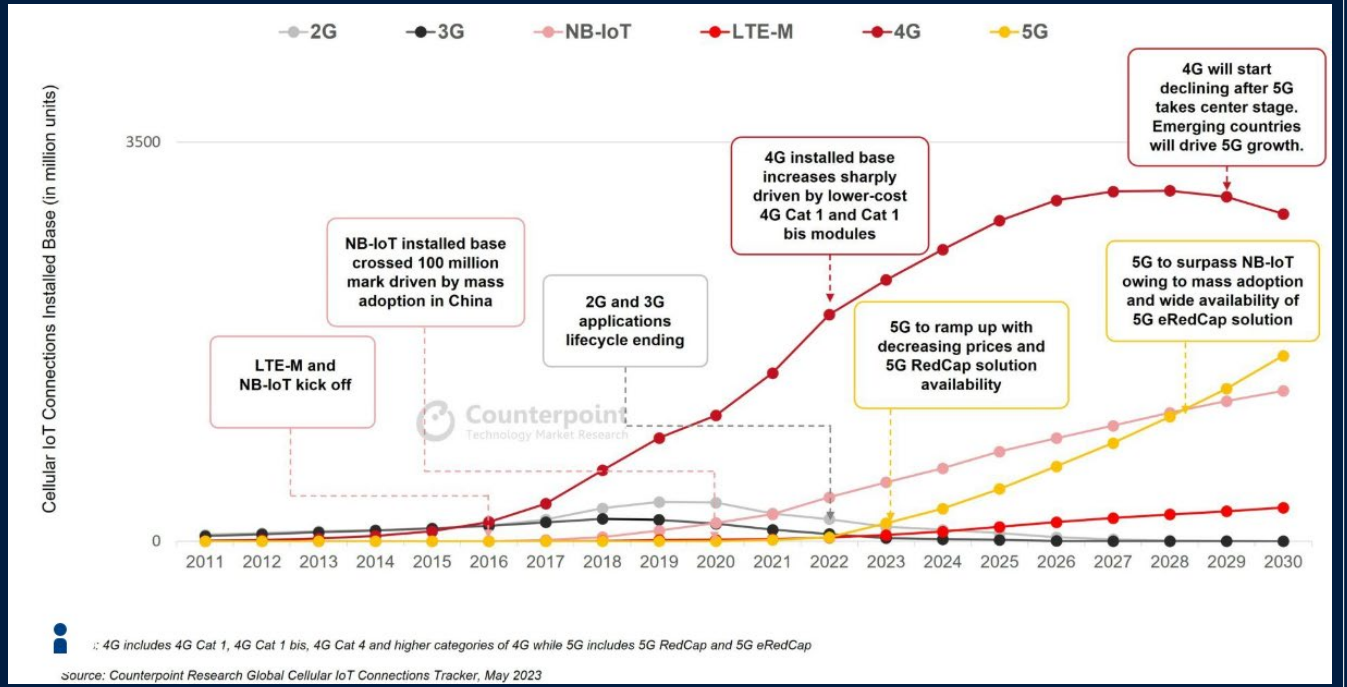
- Commercial **254**
  - 5G SA **41**
    - mmW **59**
    - 5G FWA **109**
- Investing **278**
  - Deploying SA **75**
  - 5G FWA investing **45**
- 5G private **1148**
  Deploying/trialing/investing

4G: 2,500

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



Cellular IoT Connections Installed Base

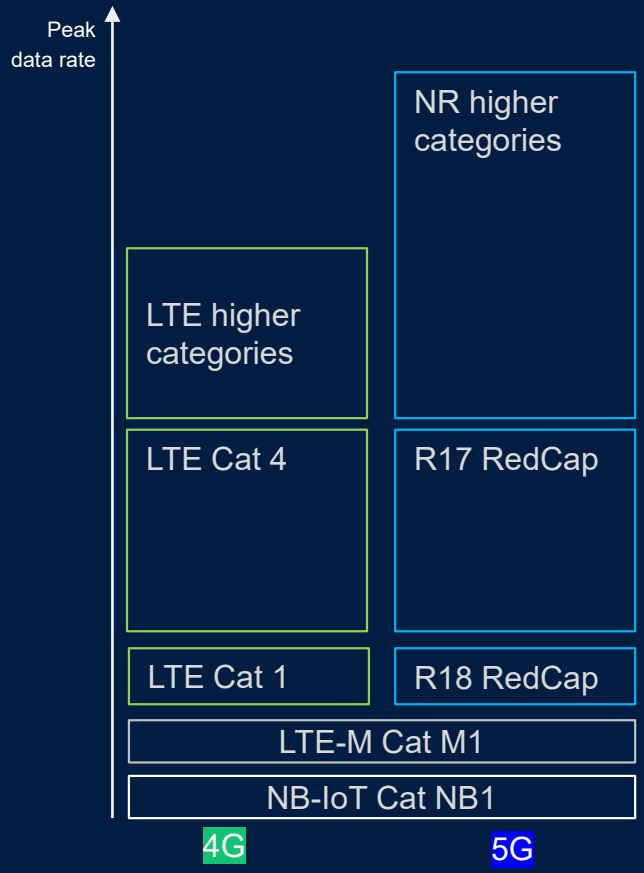


The global cellular IoT connections installed base is expected to surpass 6 billion by 2030 with a CAGR of 10.8%. The growth will be mainly driven by cellular connectivity adoption across various sectors such as utilities, automotive, industrial, retail and healthcare.

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.



Features		5G NR	5G RedCap (1T2R)	5G RedCap (1T1R)	Cat 4	Cat 1/Cat 1bis
Throughput		UL: 175 Mbps	UL: 50 Mbps	UL: 50 Mbps	UL: 50 Mbps	UL: 5 Mbps @16QAM
	FDD	DL: 350 Mbps @256QAM/2T4R/100M	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						

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, CPC
	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

RedCap Device – Optimized Features in R18

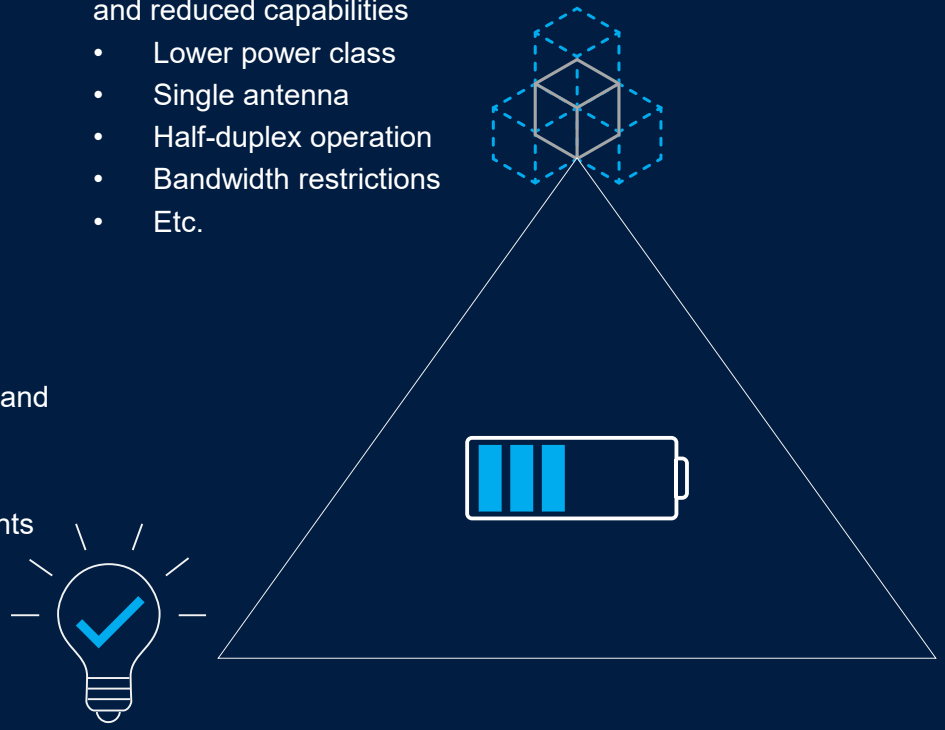
Bandwidth reduction to 5 MHz	Max bandwidth: 5 MHz (FR1), enables ~10 Mbps peak data rate
Future railway mobile communications system (FRMCS)	5G-based railway communications system, co-existence with GSM-R
RedCap for mission critical communications (MCX)	Support for direct device to device communications, 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%

RedCap Device Power Saving Cluster

Hardware restrictions
and reduced capabilities

- Lower power class
- Single antenna
- Half-duplex operation
- Bandwidth restrictions
- Etc.



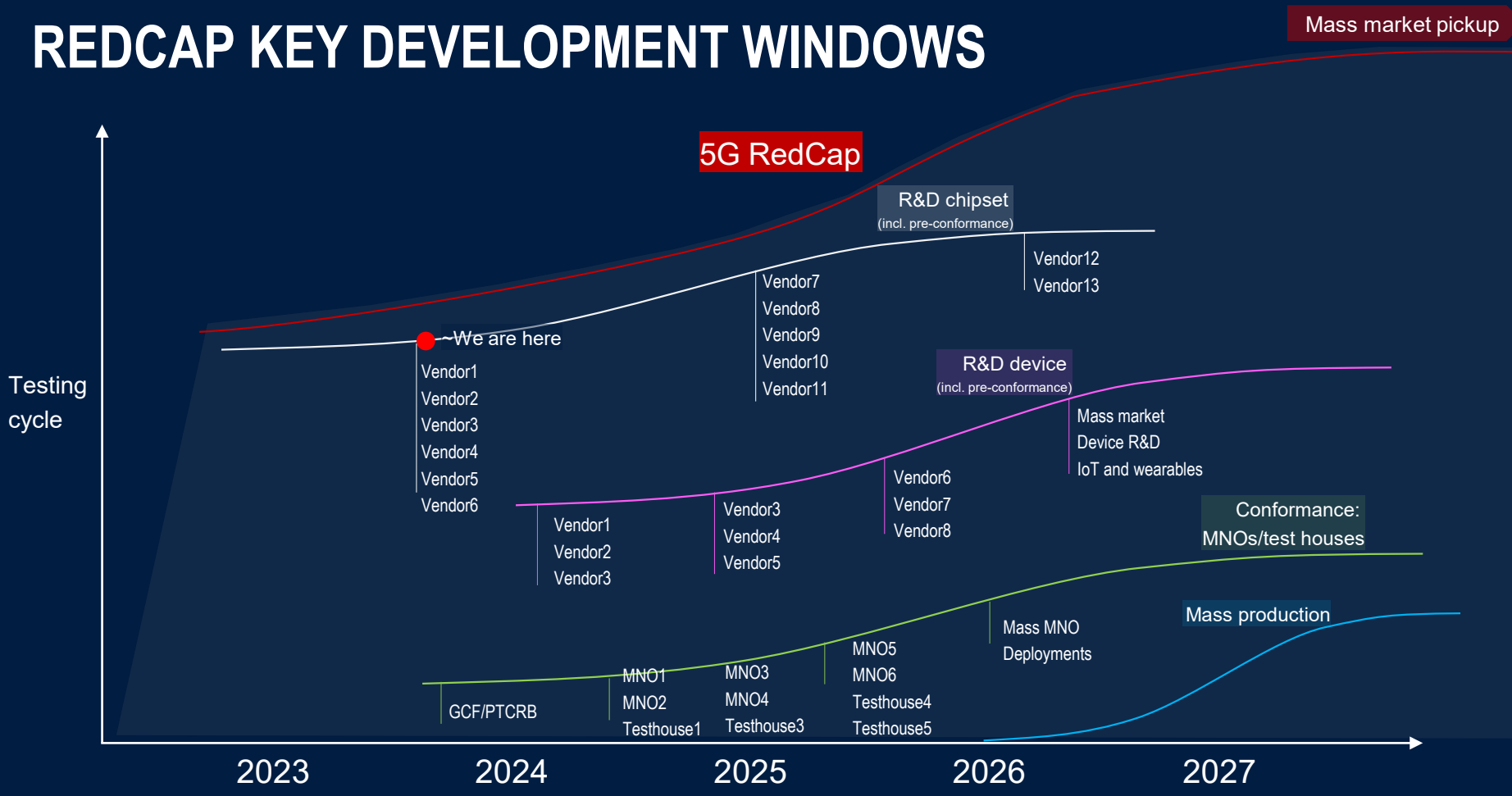
Enhanced mechanisms and
innovations

- Wake-up signals
- Relaxed measurements
- Adaptive bandwidth
- Etc.

Operational enhancements

- Discontinuous reception (DRX)
- Sleep mode
- Power save mode (PSM)
- Signaling reduction, i.e. TAU
- Cross-slot scheduling
- Etc.

REDCAP KEY DEVELOPMENT WINDOWS



CHINA REDCAP INDUSTRIAL IOT REDCAP OPPOTUNITIES

	Application	5G Redcap Industrial IoT Market Estimation
	Industrial Storage Logistics	Smart storage and logistics market size 640B CNY Storage and logistics mobile UE quantity >10M/year
	Industrial Gateways	5G connections for industrial applications can reach 100M. Assuming 20% is industrial gateway UE quantity 20M/year
	Industrial QA/Inspector	120K sets of 5G empowered QA/inspectors systems
	PLC *Programmable Logical Controller	PLC market size 12B USD globally, to reach 17B in 2027, >5% annual growth. Majority usage in chemical industry UE quantity 150M/Year
	HD Video Safety and Security	5G outdoor video safety and security equipment 11M/year by 2023
	Industrial PC/MEC	10B CNY market, >11% annual increase UE quantity 5M/Year
	HMI *Human Machine Interface	Market size 5B CNY with >10% annual growth, 2.5M/year

Source: Quectel RedCap insights

RedCap PRs

Munich / 14-Feb-2023

Leading chipset manufacturers test and verify 5G RedCap using R&S CMX500 in R&D and type approval stages

Rohde & Schwarz helps Tier 1 chipset manufacturers around the globe to verify 5G RedCap (Reduced Capabilities) and other 3GPP Release 17 features of their products. The tried and tested R&S CMX500 5G one-box signaling tester (OBT) can be used across the whole value chain, from early R&D to type approval conformance testing. At Mobile World Congress 2023 in Barcelona, Rohde & Schwarz is showcasing its radio communication tester in the new R&S CMX500 OBT lite hardware configuration, tailored specifically for lower data rate applications like 5G RedCap.

Munich / 01-Jun-2023

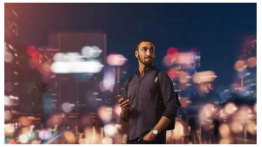
Rohde & Schwarz takes lead in number of GCF-validated 5G RedCap conformance test cases

Rohde & Schwarz has successfully validated 5G RedCap (reduced capability) test cases for its R&S CMX500 one-box signaling tester and R&S TS8980 conformance test system for the recent Conformance Agreement Group (CAG) #74 meeting, allowing the Global Certification Forum (GCF) to activate the respective work items in their device certification program. Manufacturers of IoT chipsets, modems and end devices as well as test houses can now rely on tried-and-tested Rohde & Schwarz solutions for 387 5G RedCap test cases in all device production stages, from early R&D to type approval conformance testing.

R&S联合紫光展锐在MWC共同展示RedCap测试方案

原创 罗德与施瓦茨中国 罗德与施瓦茨中国

2023-06-29 11:54 发表于上海



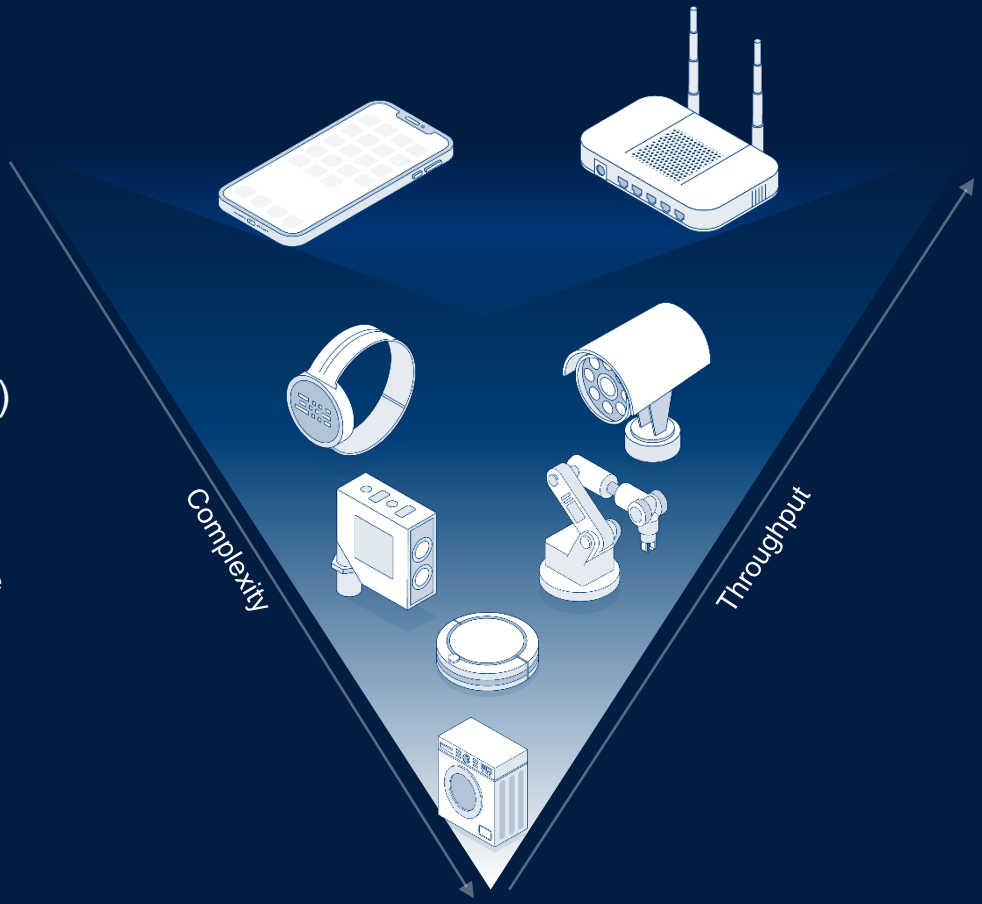
3GPP Rel17核心规范已经于2022年6月冻结，而RedCap无疑是Rel17非常重要的特性之一。RedCap定义的初衷是为了进一步降低终端复杂度和成本。

RedCap在功耗，成本以及覆盖方面略逊与NB-IoT和LTE-M，但是在速率，可靠性和延迟方面都要优于NB-IoT和LTE-M。因而RedCap的应用适用于较低复杂度和较低功耗要求的场景，比如工业无线传感器，视频监控和可穿戴设备等。

TECHNICAL ASPECTS OF TESTING REDCAP DEVICES

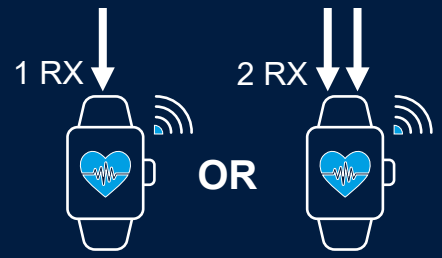
DEVICE OPTIMIZATION

- Reduced capability (RedCap)
  - 20 MHz (FR1), 100 MHz (FR2)
  - 1 or 2 RX (more complex in reality: MIMO, FR1/2 etc.)
  - 256QAM optional (FR1)
  - Half duplex FDD (but full-duplex is optional)
  - Lower transmit power (e.g. power class 7 for some bands in FR2)
  - Limited mobility/handovers (e.g. low mobility devices, relaxed RRM)



DEVICE OPTIMIZATION

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**

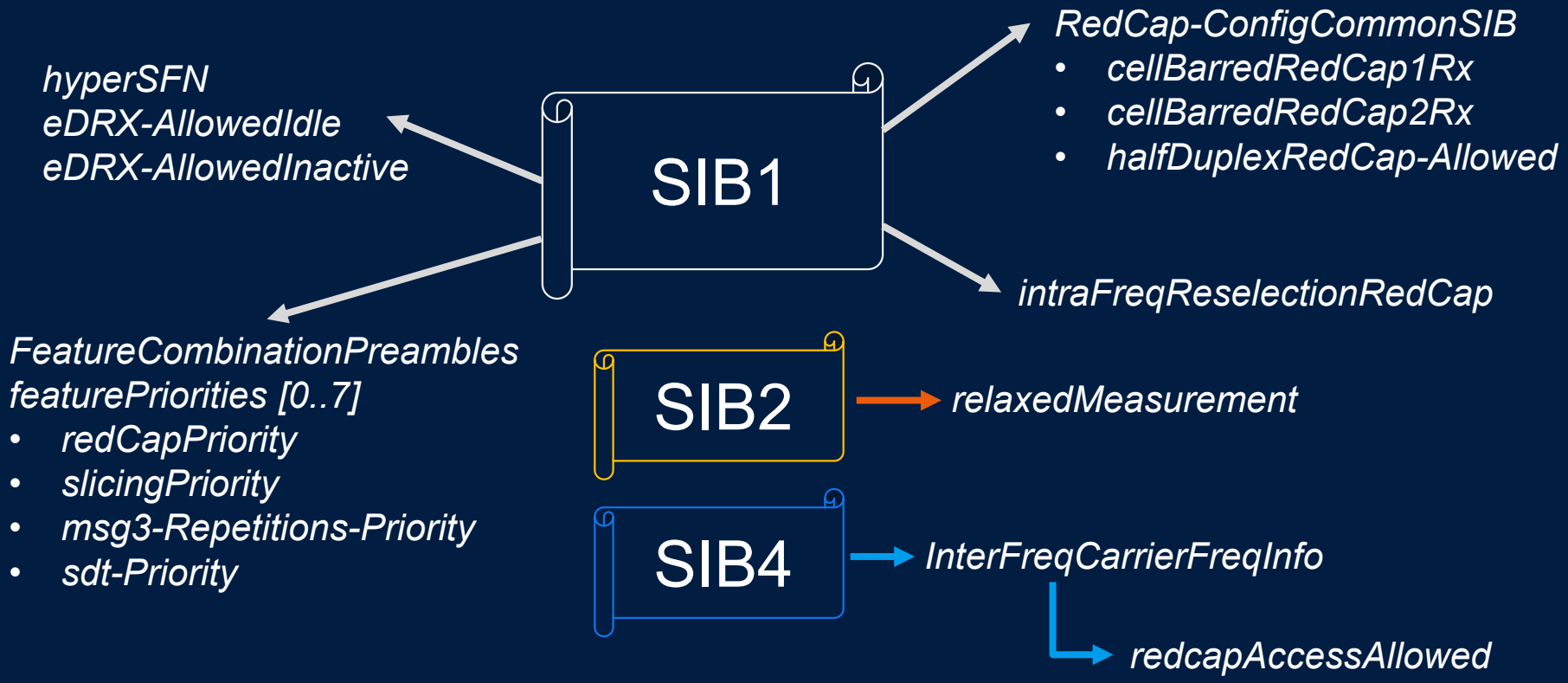
DEVICE OPTIMIZATION

Other R15-17 features may be used by a RedCap device, but they may not be optimized for them

“useful ?”
Power saving
Coverage enhancement
Positioning (will be optimized for RedCap in R18)
SDT
2-step RACH
Side link
NTN
……..

“maybe not useful?”
IIoT
URLLC
MBS
MUSIM
……..

5G NR REDCAP: System Information Broadcast



5G NR REDCAP: Cell Barring

Network can restrict access on cell level! Specific for RedCap features!
But: There is no “RedCap-only“ cell!

Cell barred for 1RX UE only

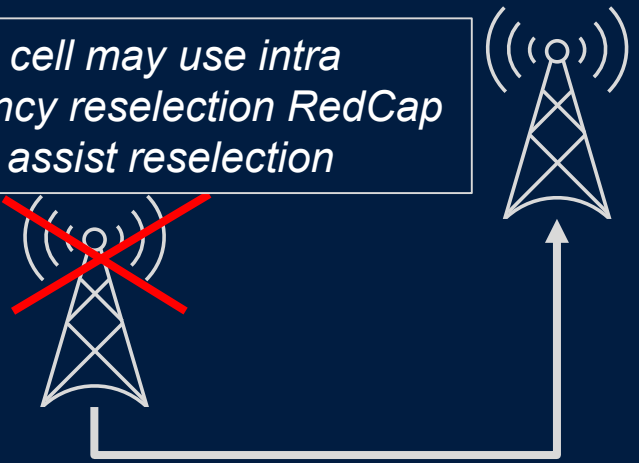
Cell barred for 2RX UE only

SIB1

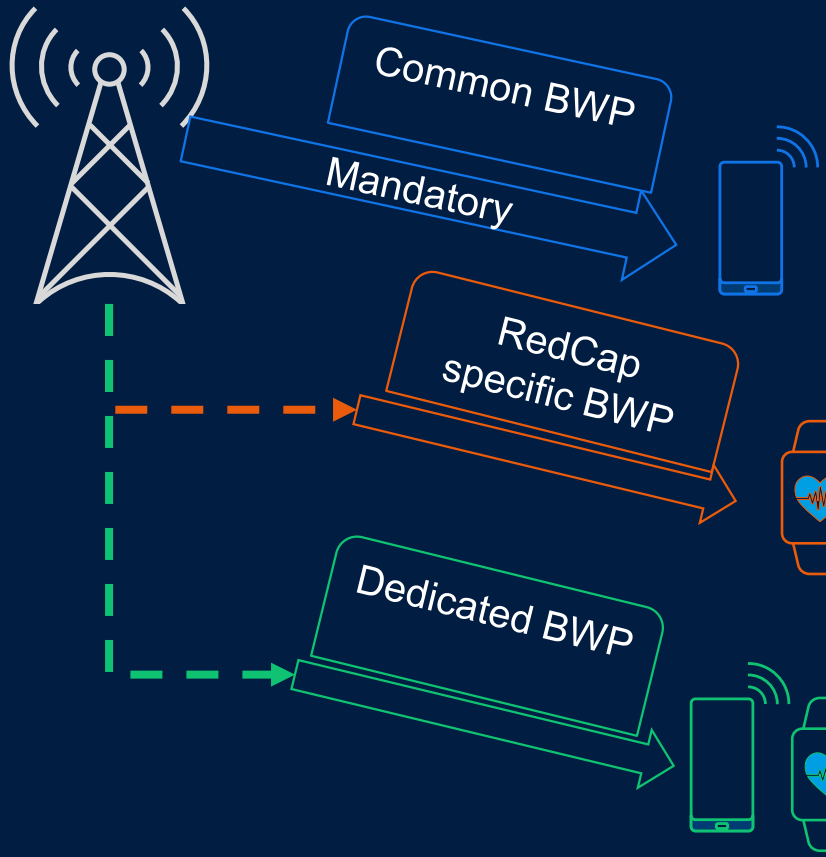
Cell barred for half-duplex UE (HD-UE)only

Barred cell may use intra frequency reselection RedCap field to assist reselection

No RedCap IAB node



5G NR REDCAP: Bandwidth Parts (BWP)

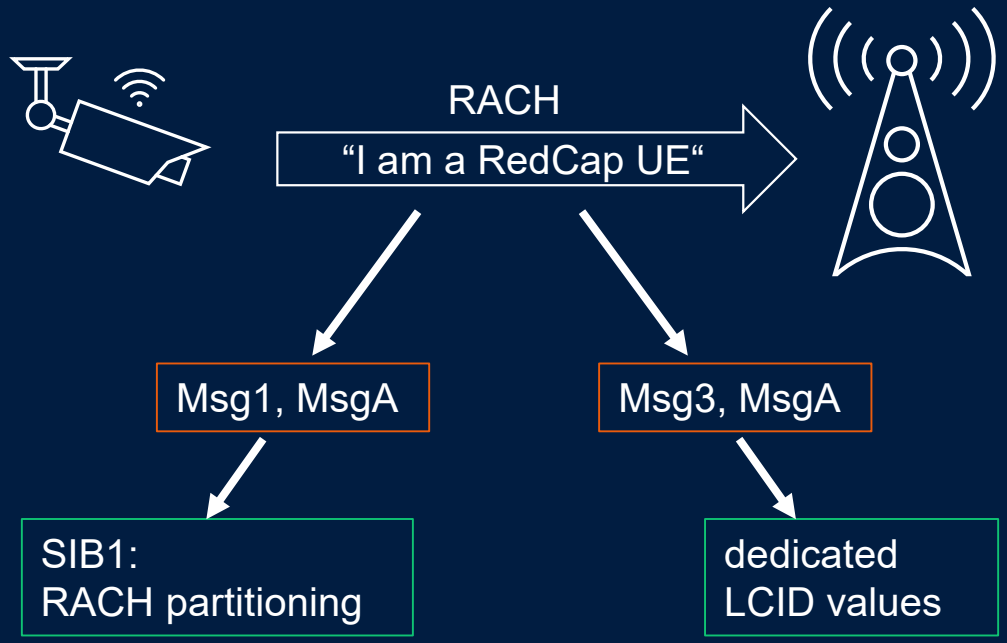


Network schedules a BWP common for all UEs. Drawback is that this BWP is not allowed to be larger than the UE capability (e.g. RedCap UE has no access)!

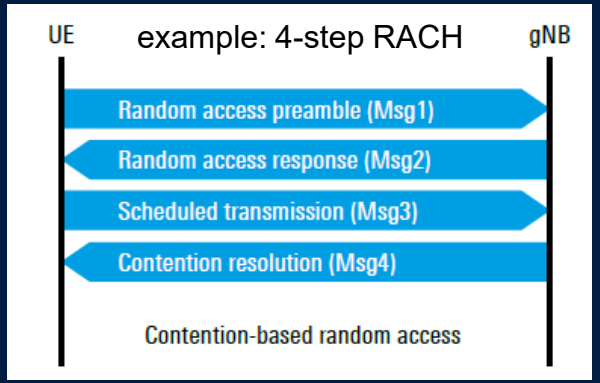
Optionally, the network schedules a BWP specific for RedCap UEs. Drawback: This BWP needs to cover the UE bandwidth, otherwise cell is considered as “barred“.

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: Early Indication

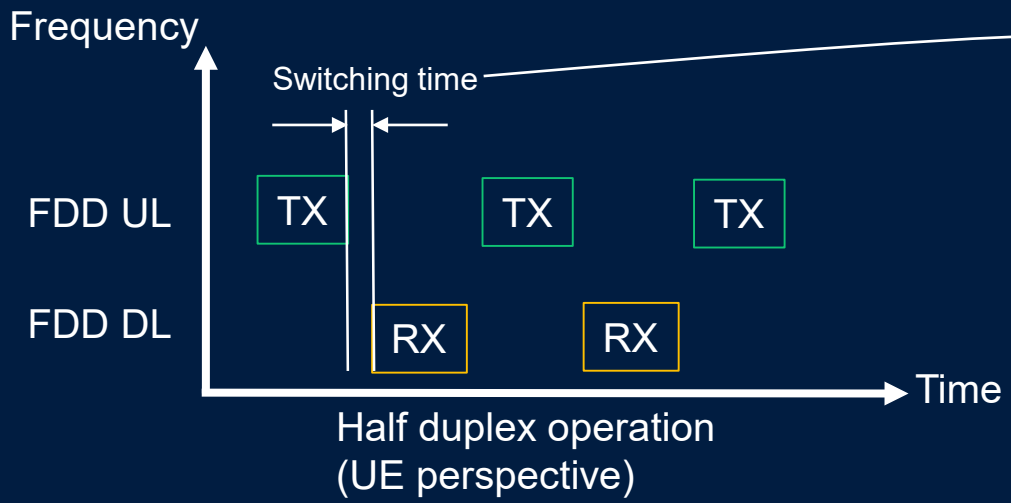


I need to know as early as possible to not exceed the UE capabilities (e.g. max BW for BWP)



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

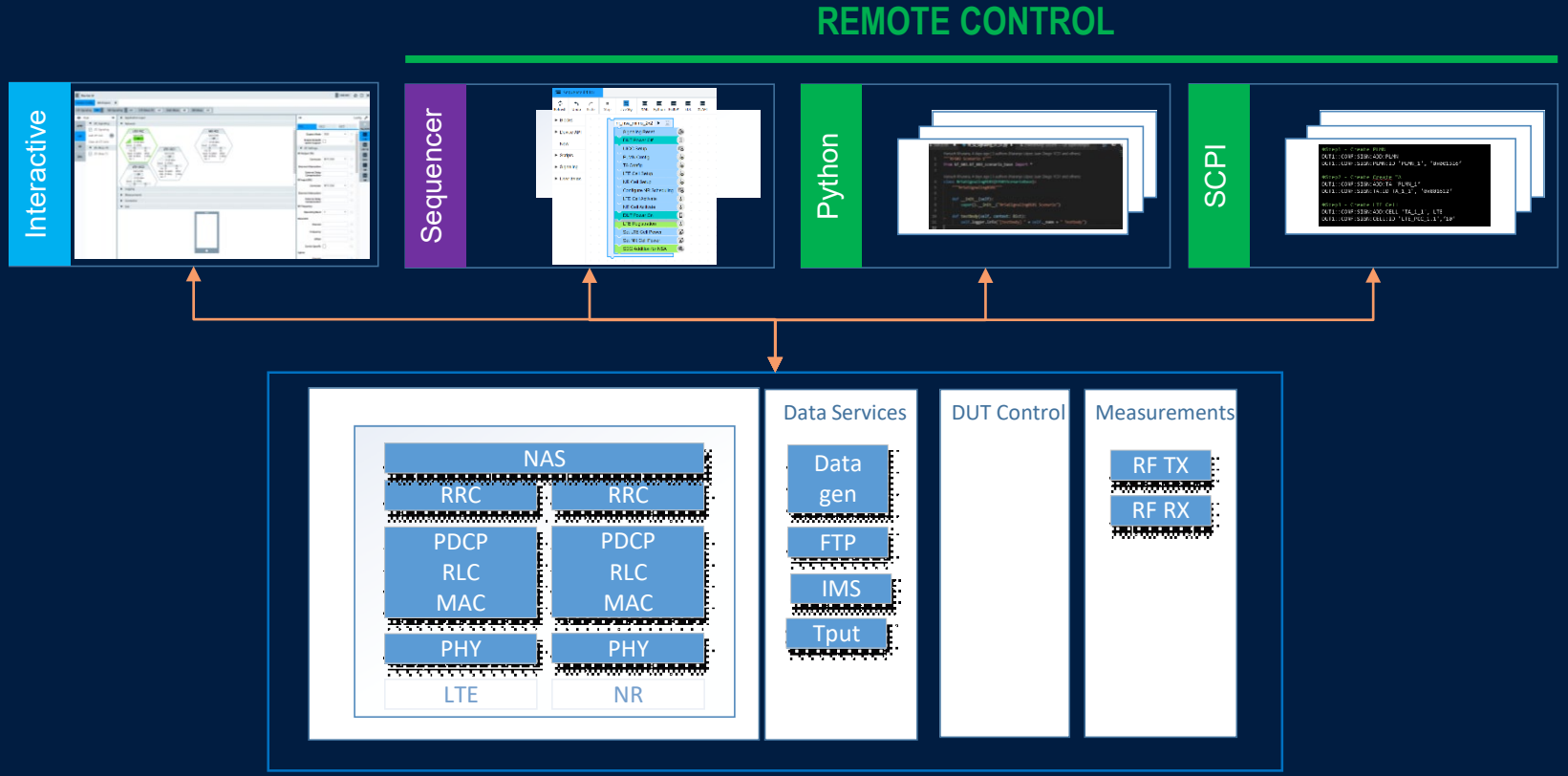
TESTING REDCAP DEVICES WITH R&S®CMX500

RedCap on OBT

- R&S®CMX500 OBT lite
- LTE, 5G NR FR1, WLAN
- Optimum configuration for 3GPP R17 RedCap RF parametric and functional test, protocol analysis and application testing
- Supports FR1/LTE 4x4 MIMO RF callbox testing
- 3GPP pre-conformance
- Data application testing

- 4 GHz RF DL iBW
- Sub8: 400 MHz - 8 GHz

R&S®CMX500 User Interfaces



R&S®CMX500 RedCap Testing Use Cases

- **XLAPI (Python) scenario package** (CMX-KF678) for early R&D protocol verification
- **Interactive callbox mode** for RF and application tests
- **Sequencer** with graphical sequencer blocks for RF, protocol and application tests
- **Protocol conformance testing** for GCF/PTCRB type approval

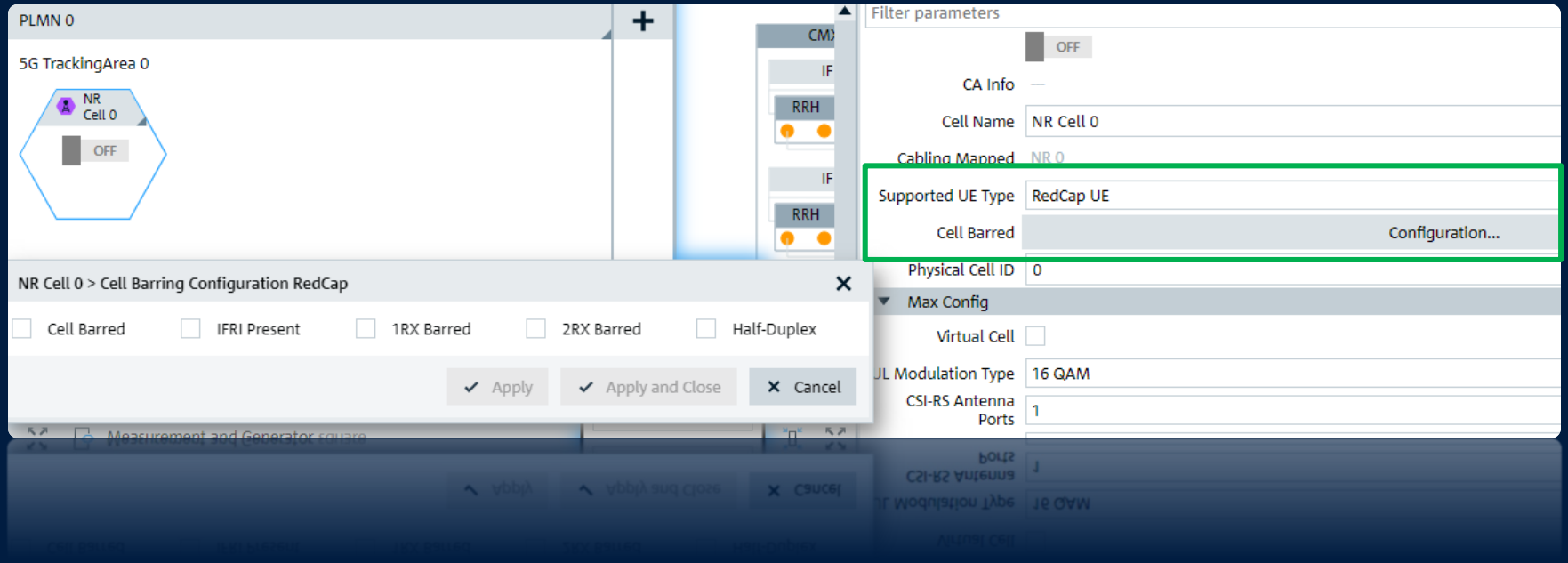
R&S®CMX-KF678X R17 RedCap Protocol Scenarios

- Dedicated RedCap XLAPI/Python **CMX-KF678X** scenario package

NR Standalone Mode Signaling Test Scripts					
Package		defined	implemented	verified Setup2	verified Setup3 (OBT)
CMX-KF603X	NR SA Signaling	40	33	29	29
CMX-KF604X	NR SA Mobility	42	32	21	23
CMX-KF606X	NR SA IMS, Service Access and Voice Call	34	26	22	19
CMX-KF678X	Release 17 Reduced Capability	20	7	0	0
Total		136	98	72	124

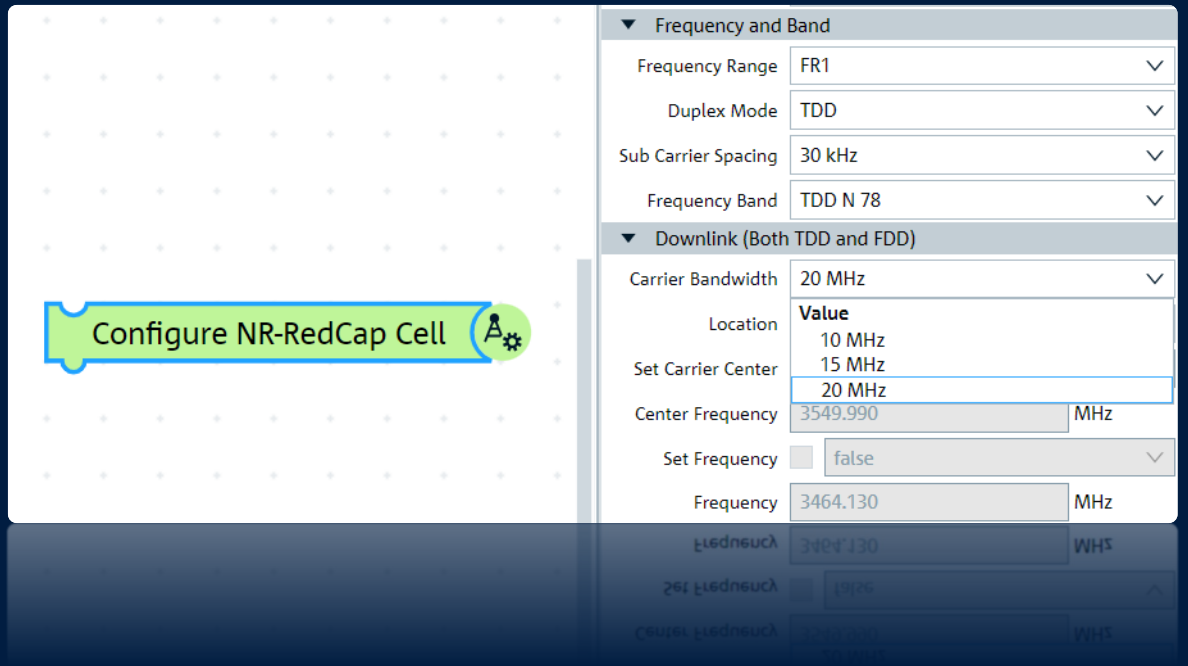
To verify whether a RedCap UE refrains from registration attempt on a higher priority NR cell which is barred for RedCap
To verify whether a RedCap UE refrains from registration attempt on a higher priority NR cell which is barred for RedCap
To verify the successful identification of a Release 17 UE as such during the UE capability transfer procedure
To verify the successful identification of a RedCap UE as such during the UE capability transfer procedure
To verify that a RedCap UE identifies itself as such by indicating in PRACH
To verify that a RedCap UE identifies itself as such by indicating in MSG3
To verify that a RedCap UE identifies itself as such by indicating in MSG-A
To verify that the maximum Initial BWP BW allowed during and after initial access is 20 MHz for a FR1 RedCap UE
To verify that the maximum Initial BWP BW allowed during and after initial access is 100 MHz for a FR1 RedCap UE
To verify that a RedCap UE starts using separate Initial DL BWP for RedCap immediately after reception of RRC Setup
To verify that a RedCap UE starts using separate Initial DL BWP for RedCap immediately after reception of RRC Setup
To verify that a RedCap UE is able to use Extended DRX on IDLE mode with cycle larger than 10.24 s
To verify that a RedCap UE can carry out RRM measurement relaxation based on stationarity criterion
To verify that a RedCap UE can carry out RRM measurement relaxation based on not-at-cell-edge criterion
To verify that a RedCap UE can carry out RRM measurement relaxation based on combined stationarity and not-at-cell-
To verify that a 1 Rx RedCap UE can properly make inter-RAT E-UTRAN handover from a NR PCell in FR1
To verify that a 2 Rx RedCap UE can properly make inter-RAT E-UTRAN handover from a NR PCell in FR1
To verify that a 1 Rx RedCap UE can properly make handover to a target NR cell using default initial BWP associated
To verify that a 2 Rx RedCap UE can properly make handover to a target NR cell using default initial BWP associated
To verify that a 1 Rx RedCap UE can properly make handover to a target NR cell using specific RedCap BWP associated
To verify that a 2 Rx RedCap UE can properly make handover to a target NR cell using specific RedCap BWP associated
To verify that a 1 Rx RedCap UE can properly make inter-RAT NR FR1 handover from a LTE PCell
To verify that a 2 Rx RedCap UE can properly make inter-RAT NR FR1 handover from a LTE PCell

3GPP R17 RedCap in R&S®CMsquares GUI

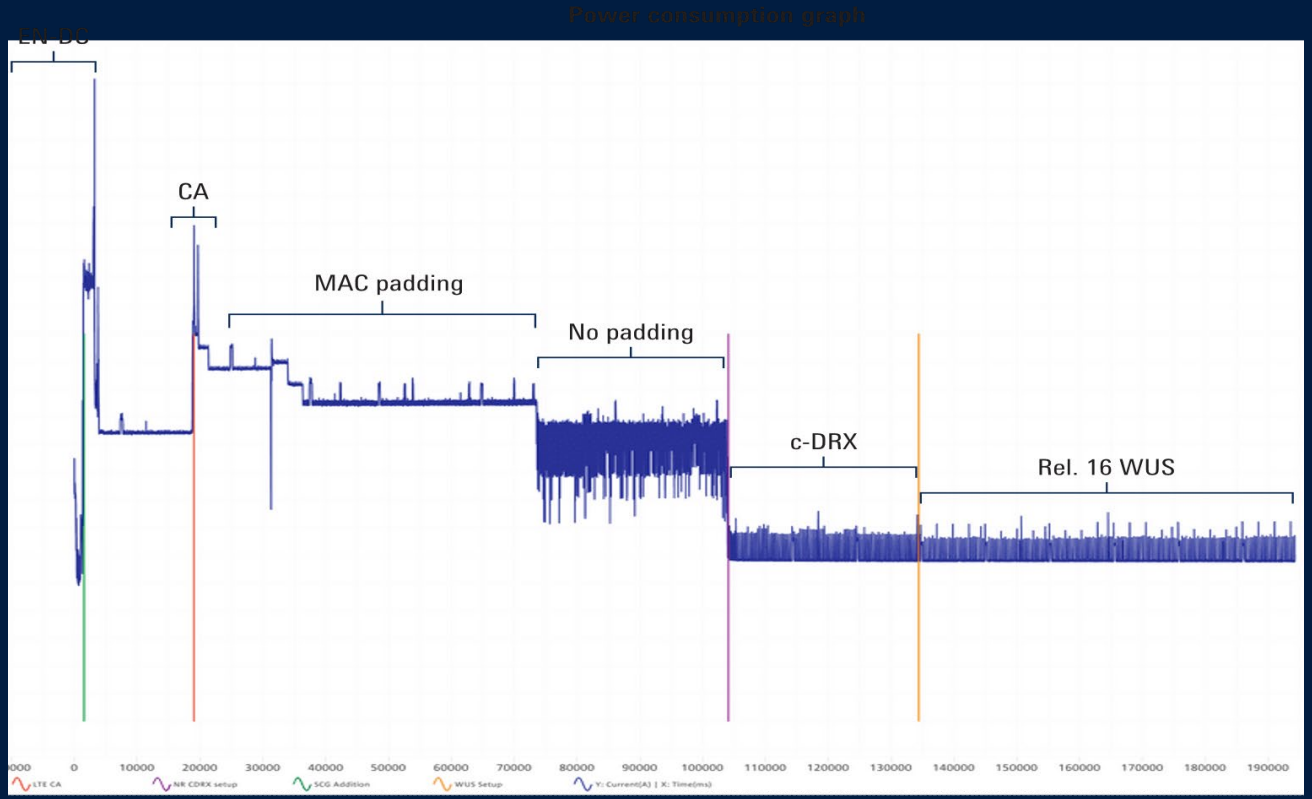


3GPP R17 RedCap Tests in R&S®CMsequencer

- New dedicated block for RedCap cell
- RedCap CMseq tests + XLAPI tests part of CMX-KF678 test package
- Similar functionality coverage in CMseq & XLAPI



Power Consumption Testing



R&S®CMX500 (TP 292) Validation Status

GCF (CAG#74) and PTCRB (PVG#100)

- Total **547 individual EN-DC and NR PCT** test cases validated
- Currently **521** TC validated at PTCRB
- **> 10500** band combinations in GCF,
- **> 7800** band combinations in PTCRB

- **R&S PCT is leading in individual TC validation**
- **R&S PCT is leading in R16 GCF validation**
- **R&S is leading in RedCap validation with R17 and R15 RedCap variant TCs**

Demo

- R&S®CMX500 OBT lite
- CMsquares User Interface
  - Callbox
  - Sequencer
  - Scripting

Find out more

www.rohde-schwarz.com/redcap

THANK YOU

ROHDE&SCHWARZ

Make ideas real