5G NR Device Testing

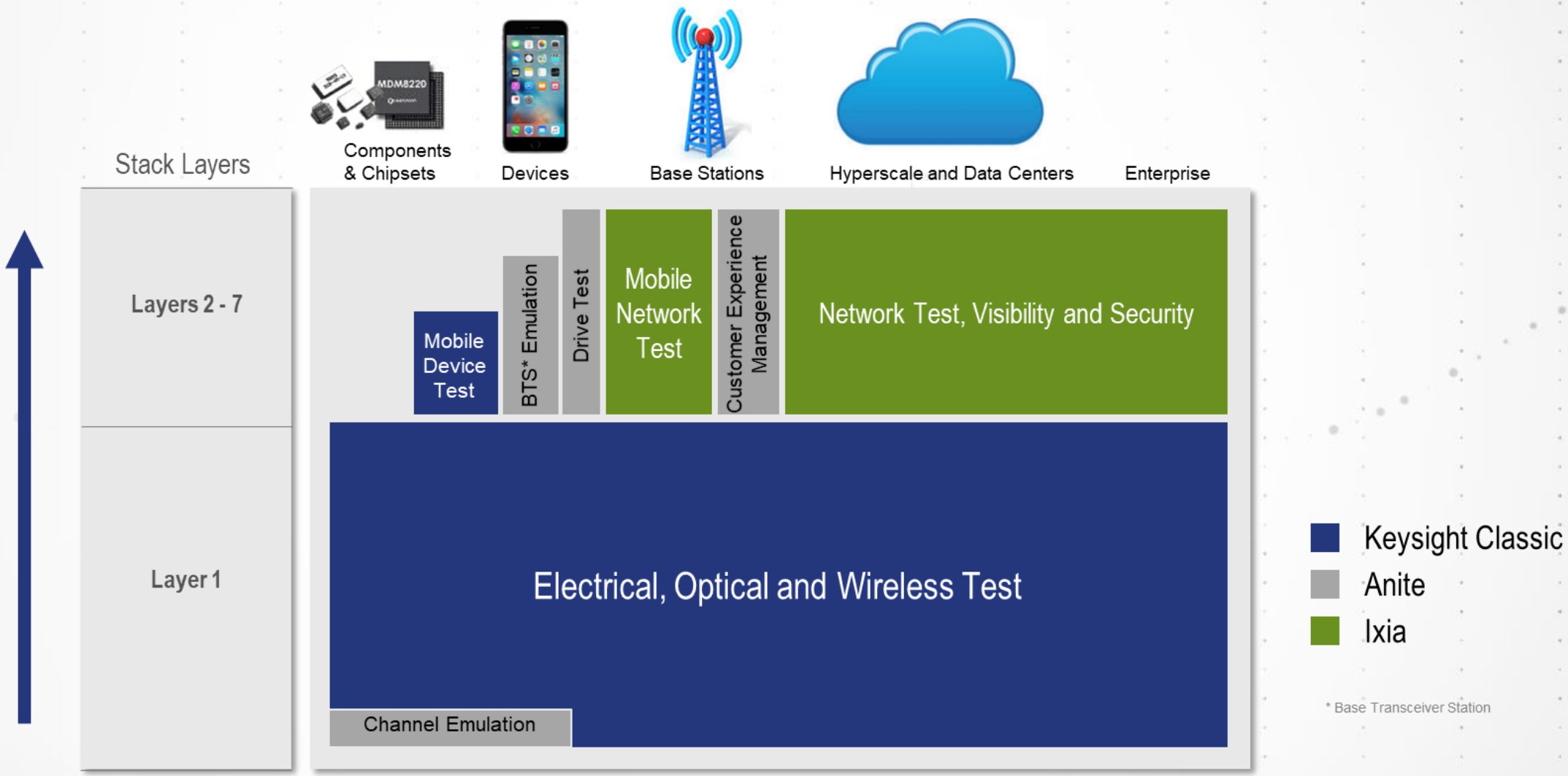
Rafa Garcia – Industry Expert

Keysight Technologies

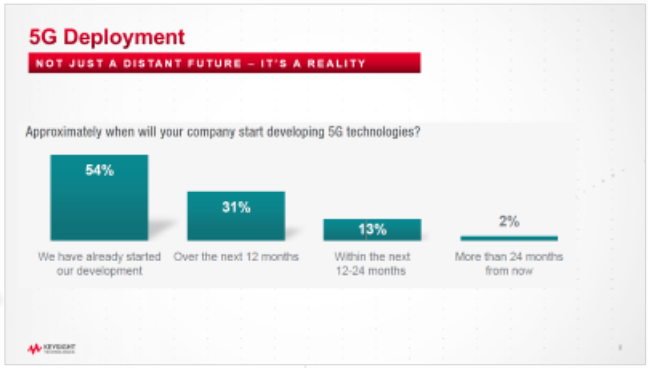
2018.11.28

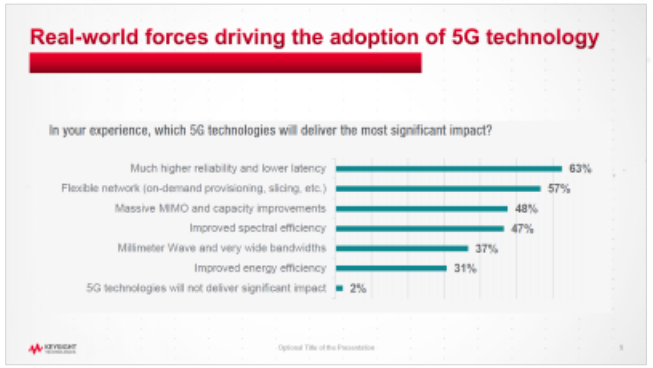
KEYSIGHT TECHNOLOGIES

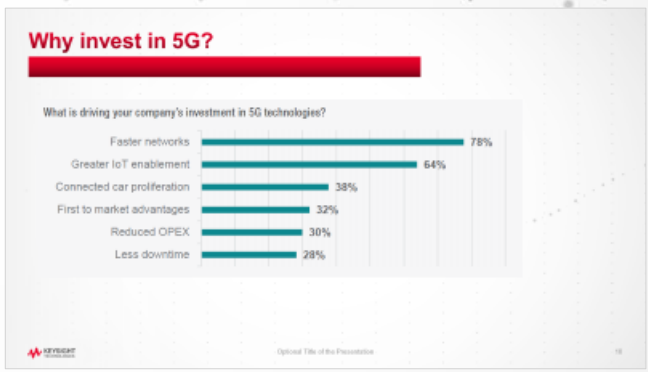
Market and Technology perspective



Keysight 2018 State of 5G Survey > 350 Companies



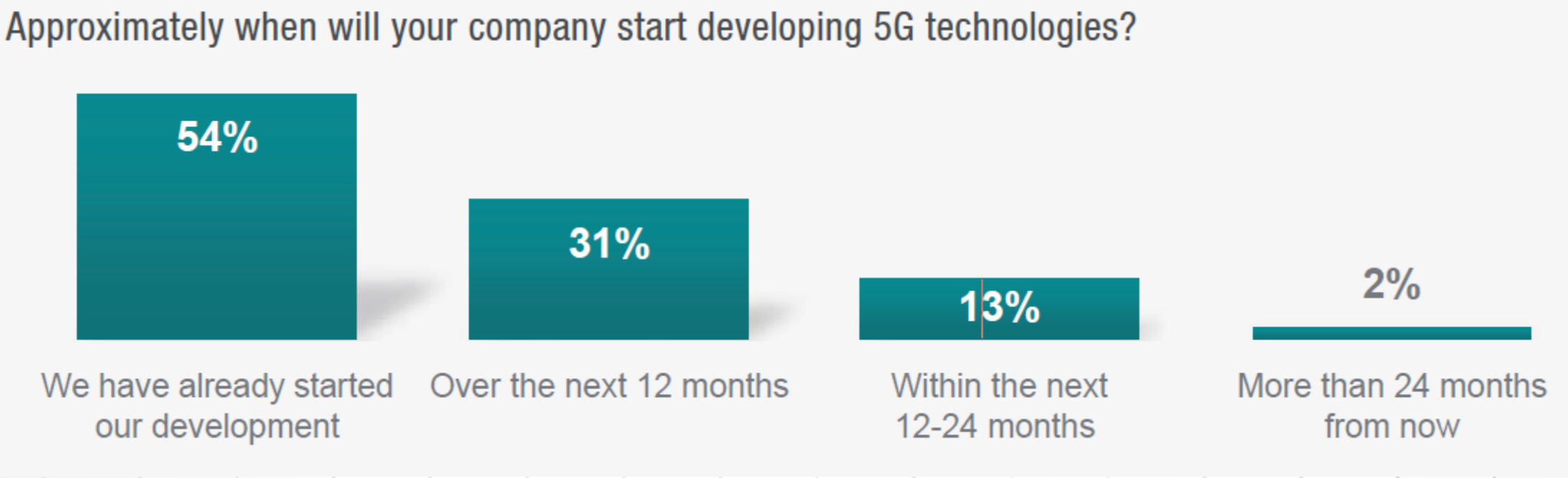




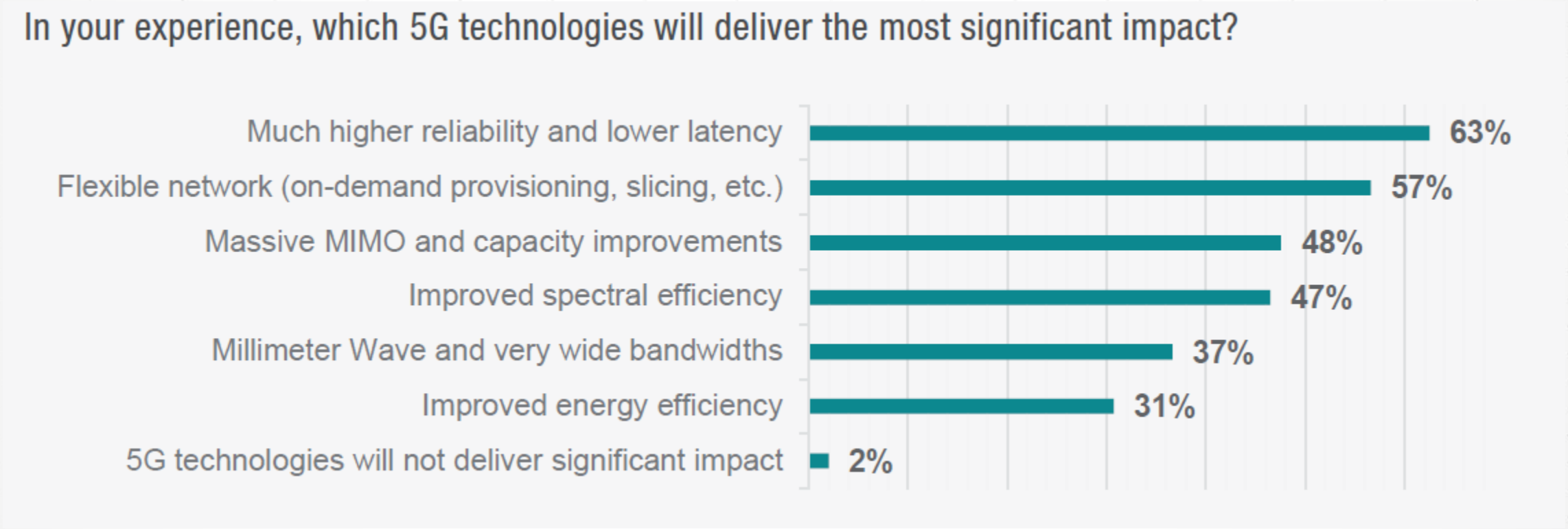
SANTA ROSA, Calif., Nov 13, 2018

5G Deployment

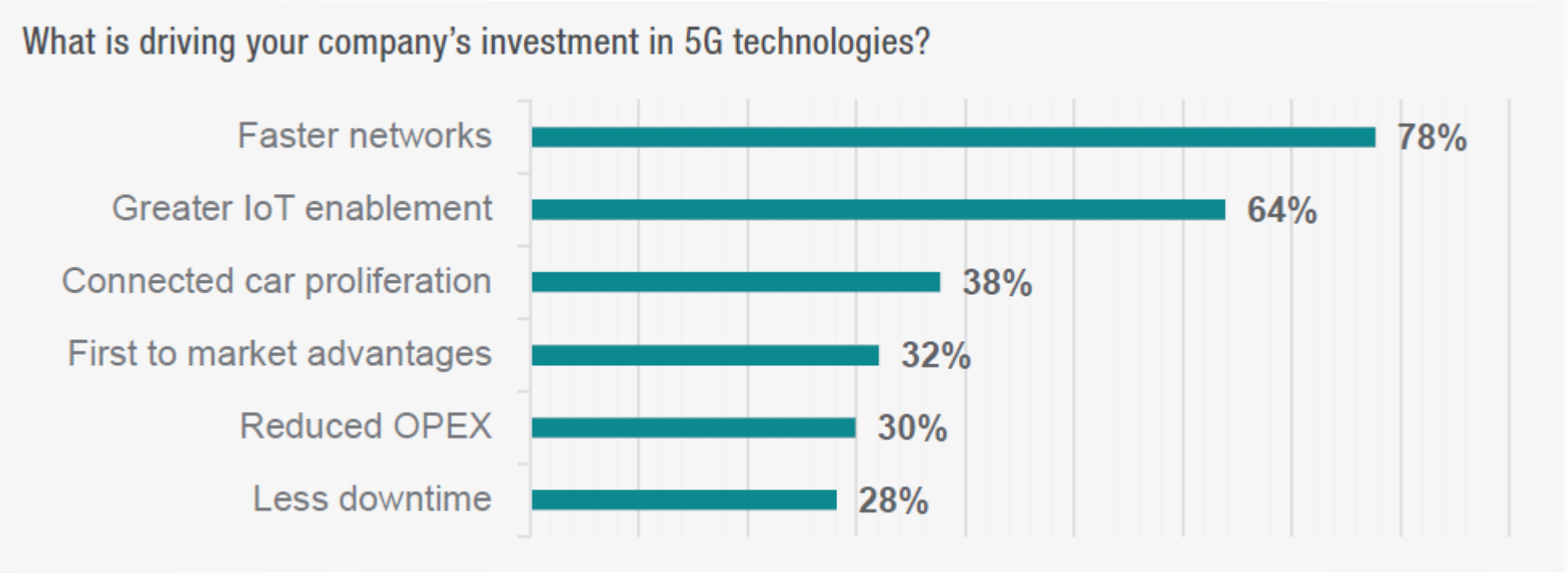
NOT JUST A DISTANT FUTURE – IT'S A REALITY



Real-world forces driving the adoption of 5G technology



Why invest in 5G?

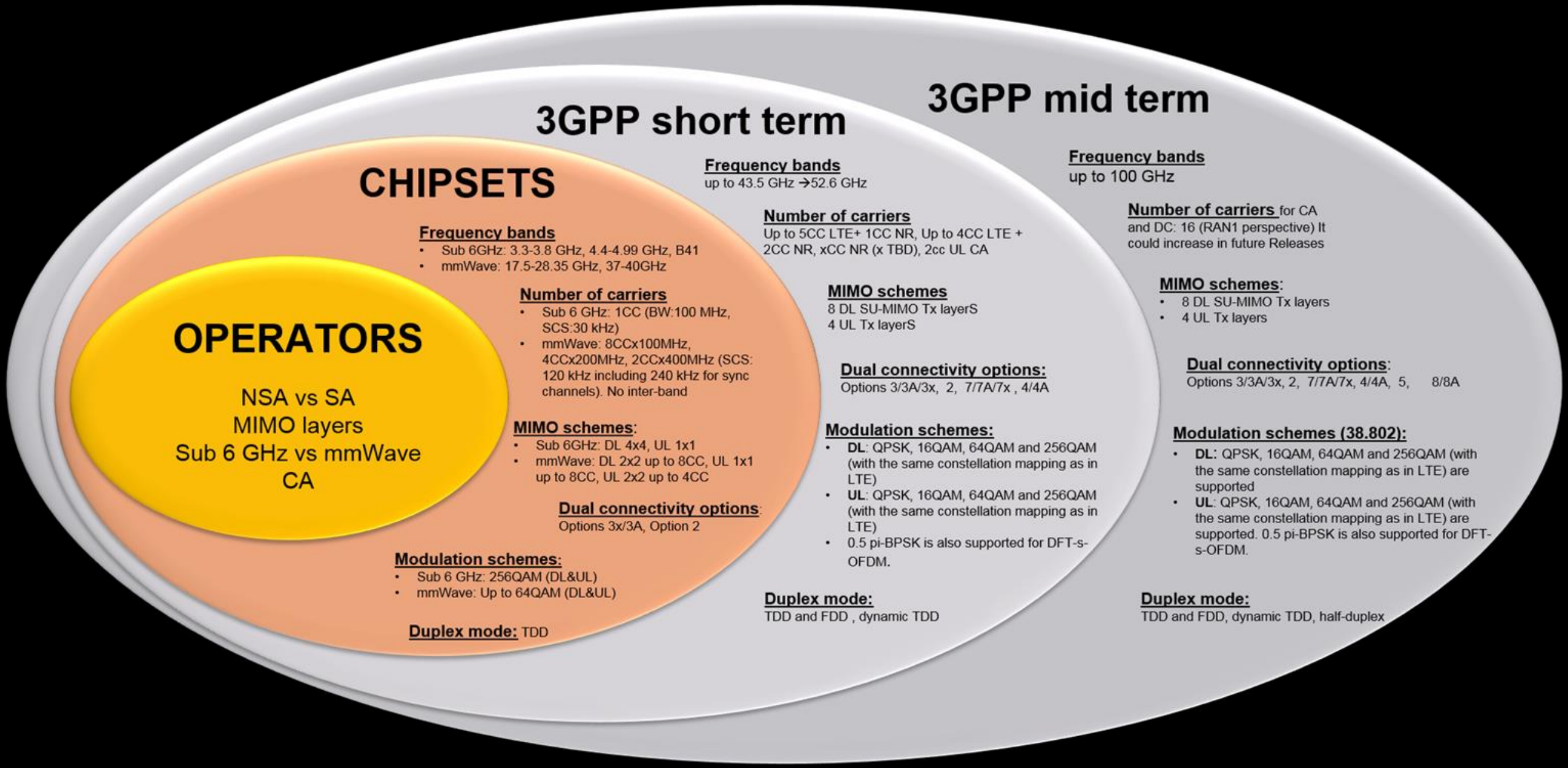


Agenda

- 5G Ecosystem
- 5G Standards
- 5G Testability Updates
- Keysight 5G Testing Solutions

5G Ecosystem

Ecosystem and features



CHIPSETS

Frequency ban
up to 43.5 GHz →52

Numbe
Up to 5CC
2CC NR, x

Frequency bands
- Sub 6GHz: 3.3-3.8 GHz, 4.4-4.99 GHz, B41
- mmWave: 17.5-28.35 GHz, 37-40GHz

Number of carriers
- Sub 6 GHz: 1CC (BW:100 MHz, SCS:30 kHz)
- mmWave: 8CCx100MHz, 4CCx200MHz, 2CCx400MHz (SCS: 120 kHz including 240 kHz for sync channels). No inter-band

OPERATORS

NSA vs SA
MIMO layers
Sub 6 GHz vs mmWave
CA

MIMO schemes:
- Sub 6GHz: DL 4x4, UL 1x1
- mmWave: DL 2x2 up to 8CC, UL 1x1 up to 8CC, UL 2x2 up to 4CC

Dual connectivity options:
Options 3x/3A, Option 2

Modulation schemes:
- Sub 6 GHz: 256QAM (DL&UL)
- mmWave: Up to 64QAM (DL&UL)

Duplex mode: TDD

Duplex
TDD and

3GPP short term

ETS

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Hz: 3.3-3.8 GHz, 4.4-4.99 GHz, B41
e: 17.5-28.35 GHz, 37-40GHz

Number of carriers
- Sub 6 GHz: 1CC (BW:100 MHz, SCS:30 kHz)
- mmWave: 8CCx100MHz, 4CCx200MHz, 2CCx400MHz (SCS: 120 kHz including 240 kHz for sync channels). No inter-band

MIMO schemes:
- Sub 6GHz: DL 4x4, UL 1x1
- mmWave: DL 2x2 up to 8CC, UL 1x1 up to 8CC, UL 2x2 up to 4CC

Dual connectivity options:
Options 3x/3A, Option 2

schemes:
256QAM (DL&UL)
p to 64QAM (DL&UL)

Frequency bands
up to 43.5 GHz →52.6 GHz

Number of carriers
Up to 5CC LTE+ 1CC NR, Up to 4CC LTE + 2CC NR, xCC NR (x TBD), 2cc UL CA

MIMO schemes
8 DL SU-MIMO Tx layerS
4 UL Tx layerS

Dual connectivity options:
Options 3/3A/3x, 2, 7/7A/7x , 4/4A

Modulation schemes:
- **DL**: QPSK, 16QAM, 64QAM and 256QAM (with the same constellation mapping as in LTE)
- **UL**: QPSK, 16QAM, 64QAM and 256QAM (with the same constellation mapping as in LTE)
- 0.5 pi-BPSK is also supported for DFT-s-OFDM.

Duplex mode:
TDD and FDD , dynamic TDD

Frequency ban
up to 100 GHz

Numbe
and DC: 1
could incr

MIM
- 8
- 4

M
-
-

Duple
TDD an

3GPP mid term

Frequency bands
up to 100 GHz

rriers
CC NR, Up to 4CC LTE +
(x TBD), 2cc UL CA

schemes
U-MIMO Tx layerS
layerS

l connectivity options:
ns 3/3A/3x, 2, 7/7A/7x , 4/4A

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DM.

namic TDD

Number of carriers for CA and DC: 16 (RAN1 perspective) It could increase in future Releases

MIMO schemes:
- 8 DL SU-MIMO Tx layers
- 4 UL Tx layers

Dual connectivity options:
Options 3/3A/3x, 2, 7/7A/7x, 4/4A, 5, 8/8A

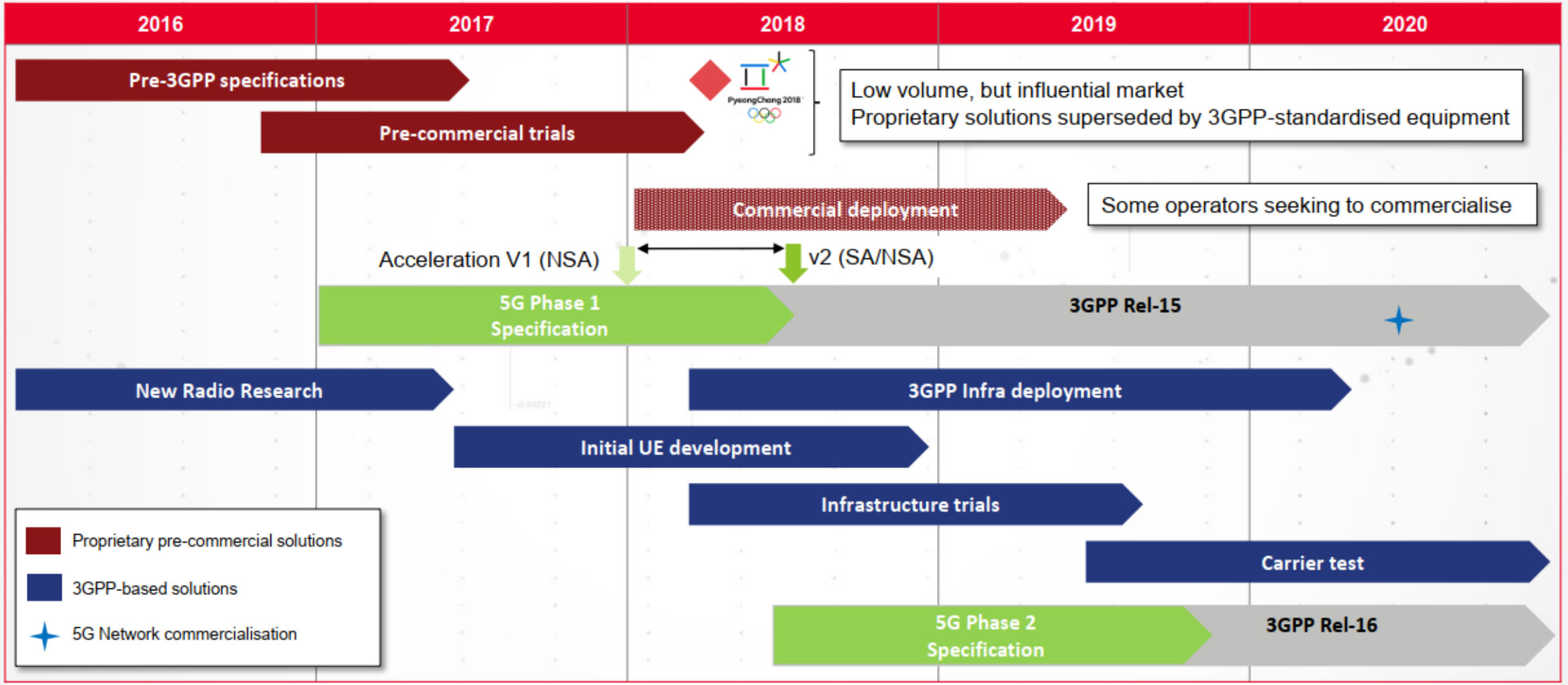
Modulation schemes (38.802):
- **DL**: QPSK, 16QAM, 64QAM and 256QAM (with the same constellation mapping as in LTE) are supported
- **UL**: QPSK, 16QAM, 64QAM and 256QAM (with the same constellation mapping as in LTE) are supported. 0.5 pi-BPSK is also supported for DFT-s-OFDM.

Duplex mode:
TDD and FDD, dynamic TDD, half-duplex

5G Standards

5G Standards Development

PROGRESS AND TIMELINE



3GPP Specifications

- Specifications structured in Releases
- Stable platform for implementation of features
- Addition of new features
- Phases, related to a specific technology

How many releases, when did they start?

3GPP Specifications

RELEASE	DATE	INFORMATION
Phase 1	1992	GSM Features
Phase 2	1995	GSM Features, EFR Codec,
Release 96	1997 Q1	GSM Features, 14.4 kbit/s User Data Rate,
Release 97	1998 Q1	GSM Features, GPRS
Release 98	1999 Q1	GSM Features, AMR, EDGE, GPRS for PCS1900
Release 99	2000 Q1	Specified the first UMTS 3G networks, incorporating a CDMA air interface[9]
Release 4	2001 Q2	Originally called the **Release 2000** – added features including an all-IP Core Network[10]
Release 5	2002 Q1	Introduced IMS and HSDPA[11]
Release 6	2004 Q4	Integrated operation with Wireless LAN networks and adds HSUPA, MBMS, enhancements to IMS such as Push
Release 7	2007 Q4	Focuses on decreasing latency, improvements to QoS and real-time applications such as VoIP.[13] This specific Access Evolution), SIM high-speed protocol and contactless front-end interface (Near Field Communication enc like Mobile Payments), EDGE Evolution.
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Release 10	2011 Q1	LTE Advanced fulfilling IMT Advanced 4G requirements. Backwards compatible with release 8 (LTE). Multi-Cell HSDPA (4 carriers).
Release 11	2012 Q3	Advanced IP Interconnection of Services. Service layer interconnection between national operators/carriers as well as third party application providers. Heterogeneous networks (HetNet) improvements, Coordinated Multi-Point operation (CoMP). In-device Co-existence (IDC).

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Release 13	2016 Q1	LTE in unlicensed, LTE enhancements for Machine-Type Communication. Elevation Beamforming / Full-Dimension MIMO, Indoor positioning.[15] LTE-Advanced Pro.
Release 14	June 2017*	Energy Efficiency, Location Services (LCS), Mission Critical Data over LTE, Mission Critical Video over LTE, Flexible Mobile Service Steering (FMSS), Multimedia Broadcast Supplement for Public Warning System (MBSP), enhancement for TV service, massive Internet of Things, Cell Broadcast Service (CBS)[16]
Release 15	Sept 2018*	Support for 5G Vehicle-to-x service,IP Multimedia Core Network Subsystem (IMS), Future Railway Mobile Communication System[17]

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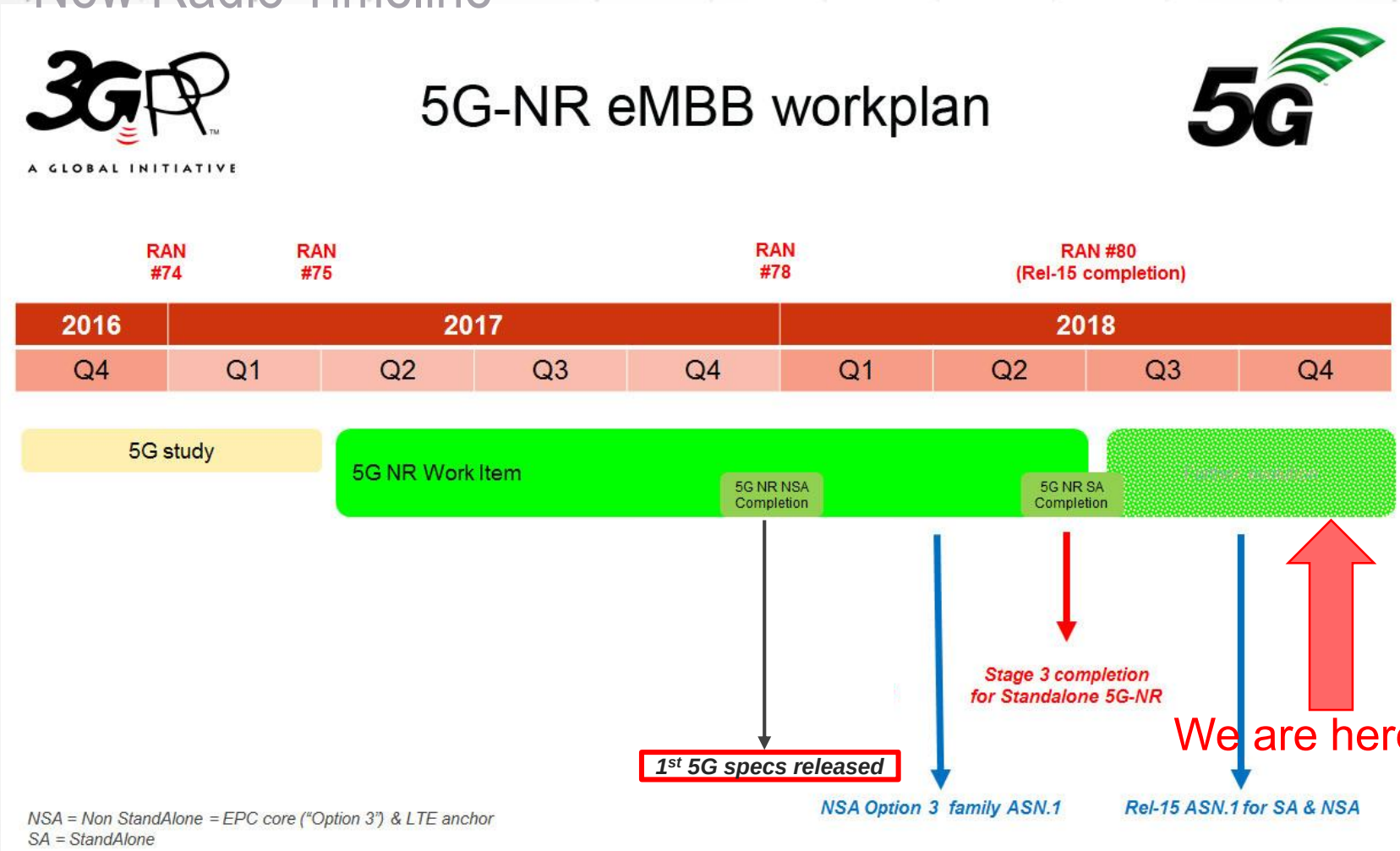
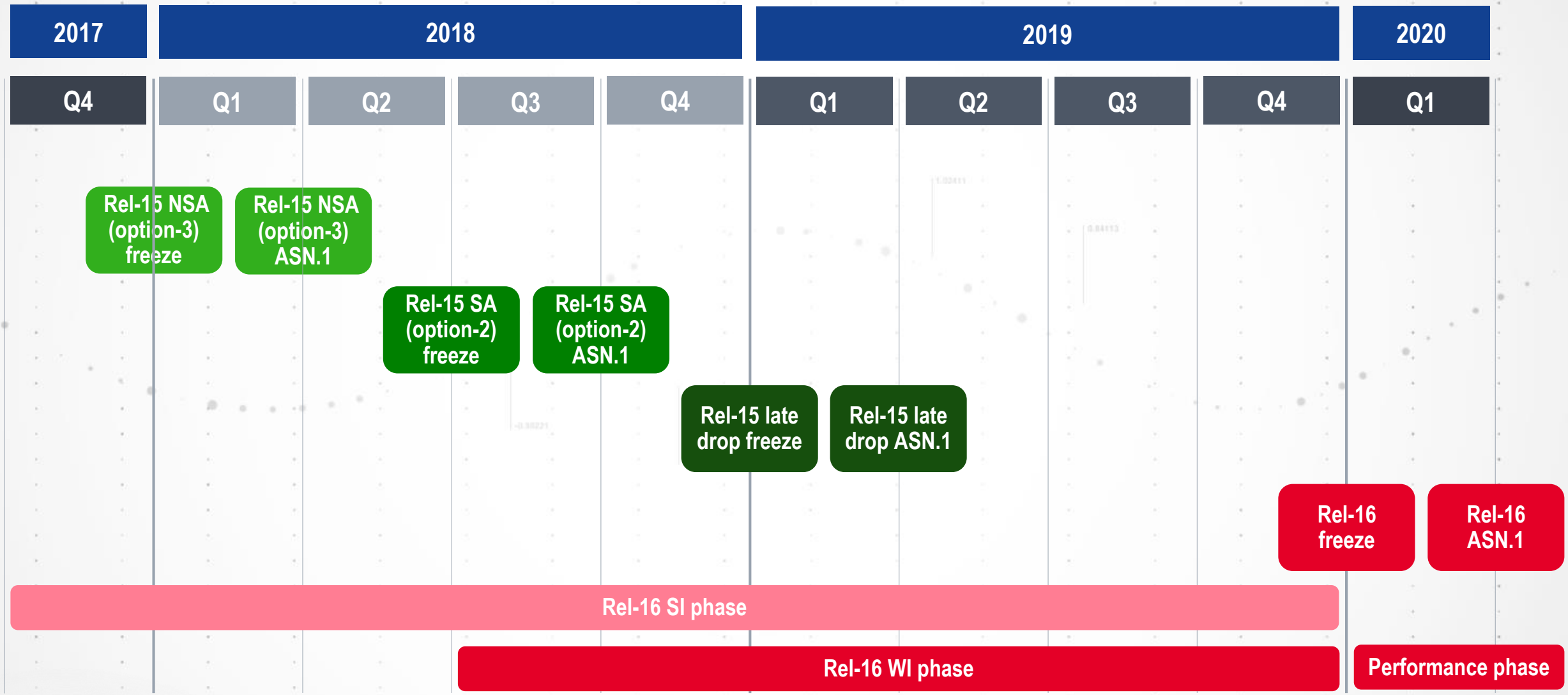
eMBB acceleration

New Radio Timeline



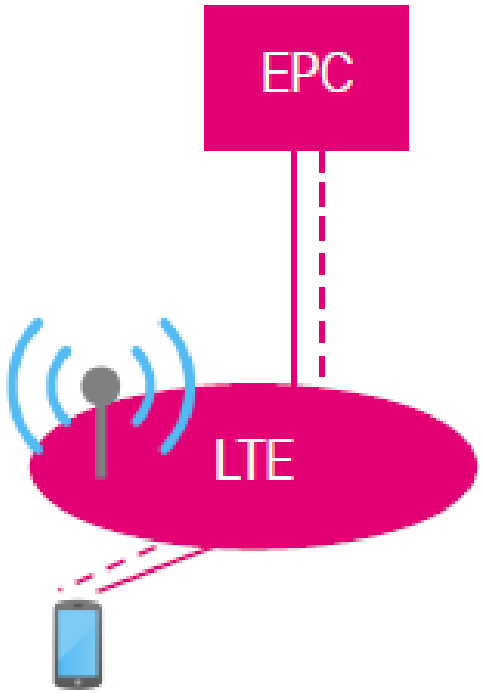
- 1st 5G specification version released in Dec 2017 for NSA (Option 3)
- Lot of maintenance work in H12018 to stabilize the specs
- ASN1 for NSA agreed to be frozen for NSA in Mar 2018
- Additional work to complete SA (Option 2) by Jun 2018
- Additional work to define basic URLLC by June 2018
- Additional dual connectivity options (Opt 4 and 7) couldn't be completed by Jun 2018 despite operators requests

5G 3GPP Releases Timeline

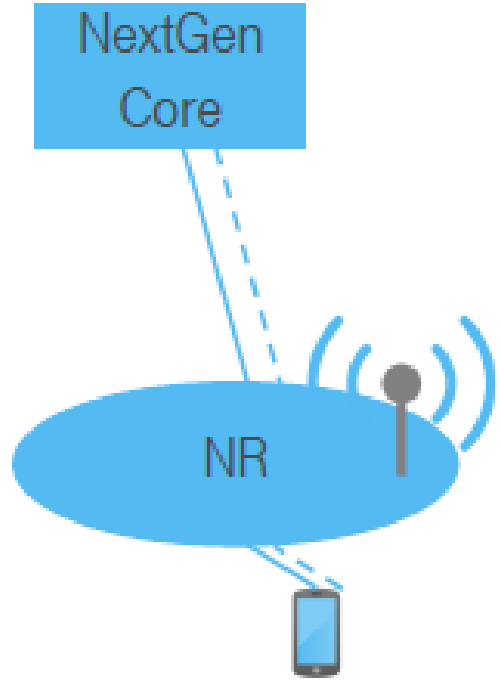


Dual Connectivity options

1) Standalone LTE, EPC connected - legacy



2) Standalone NR, NGCN connected



Source: 3GPP RAN#72, RP-161266"

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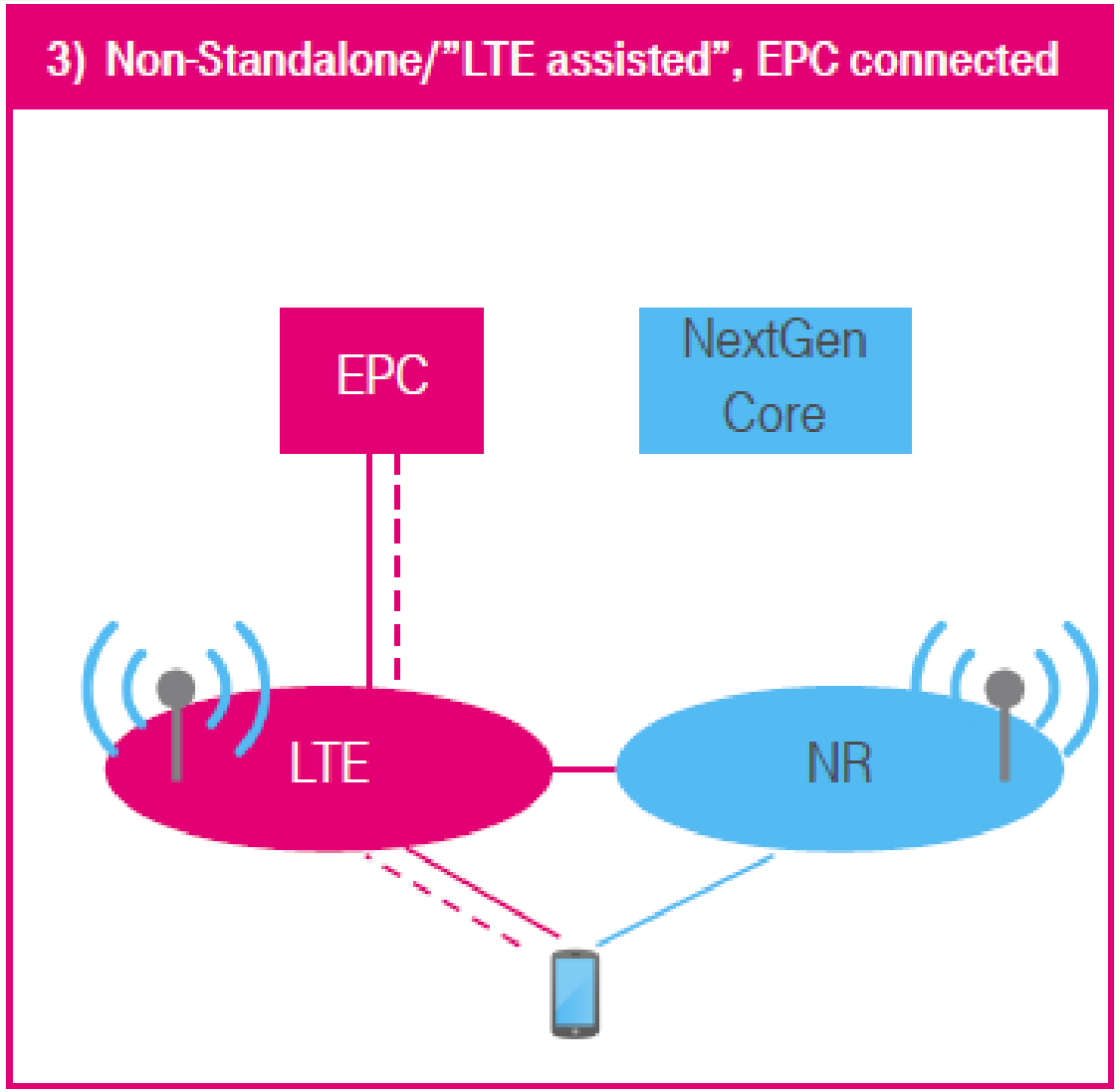

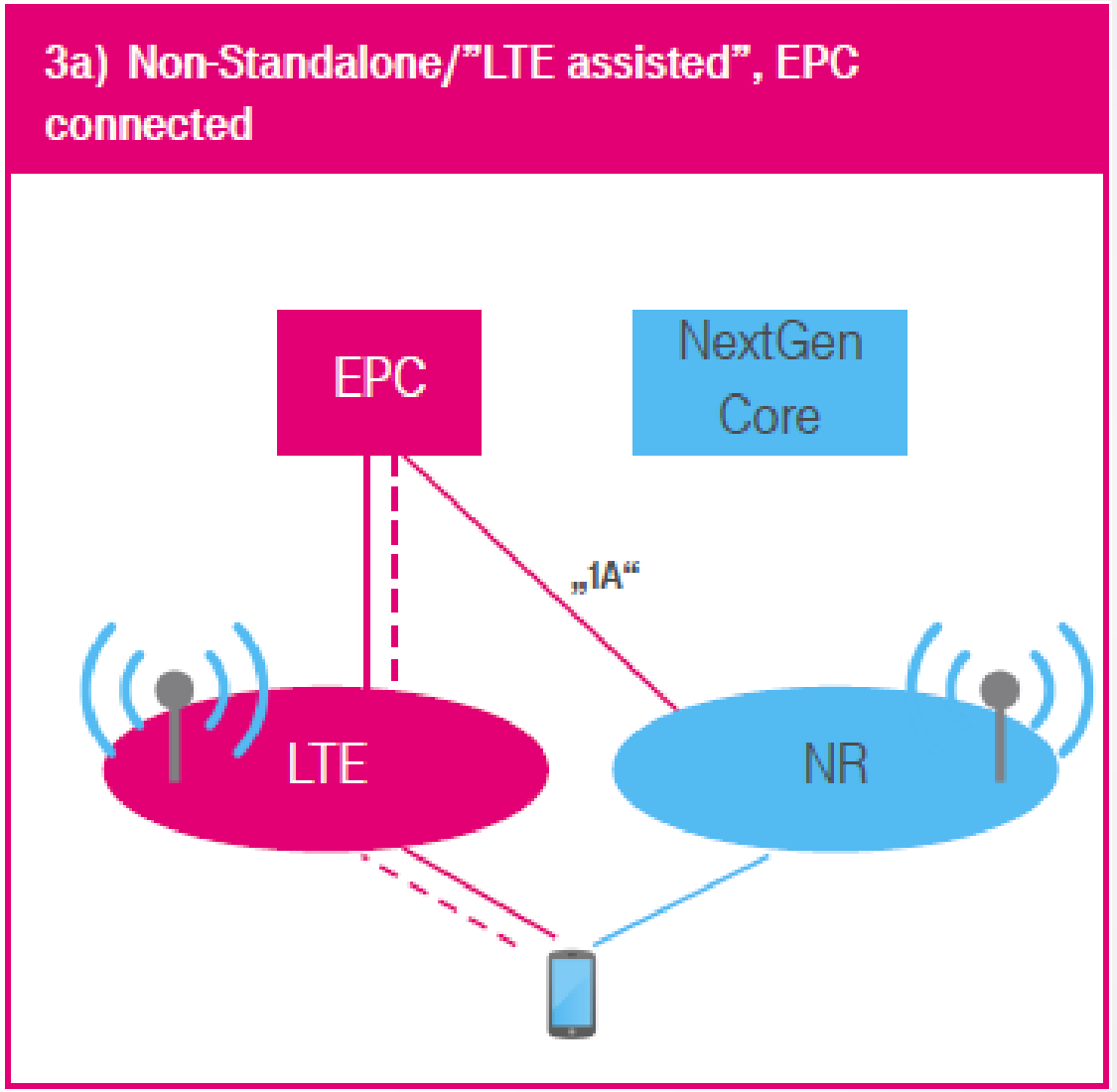

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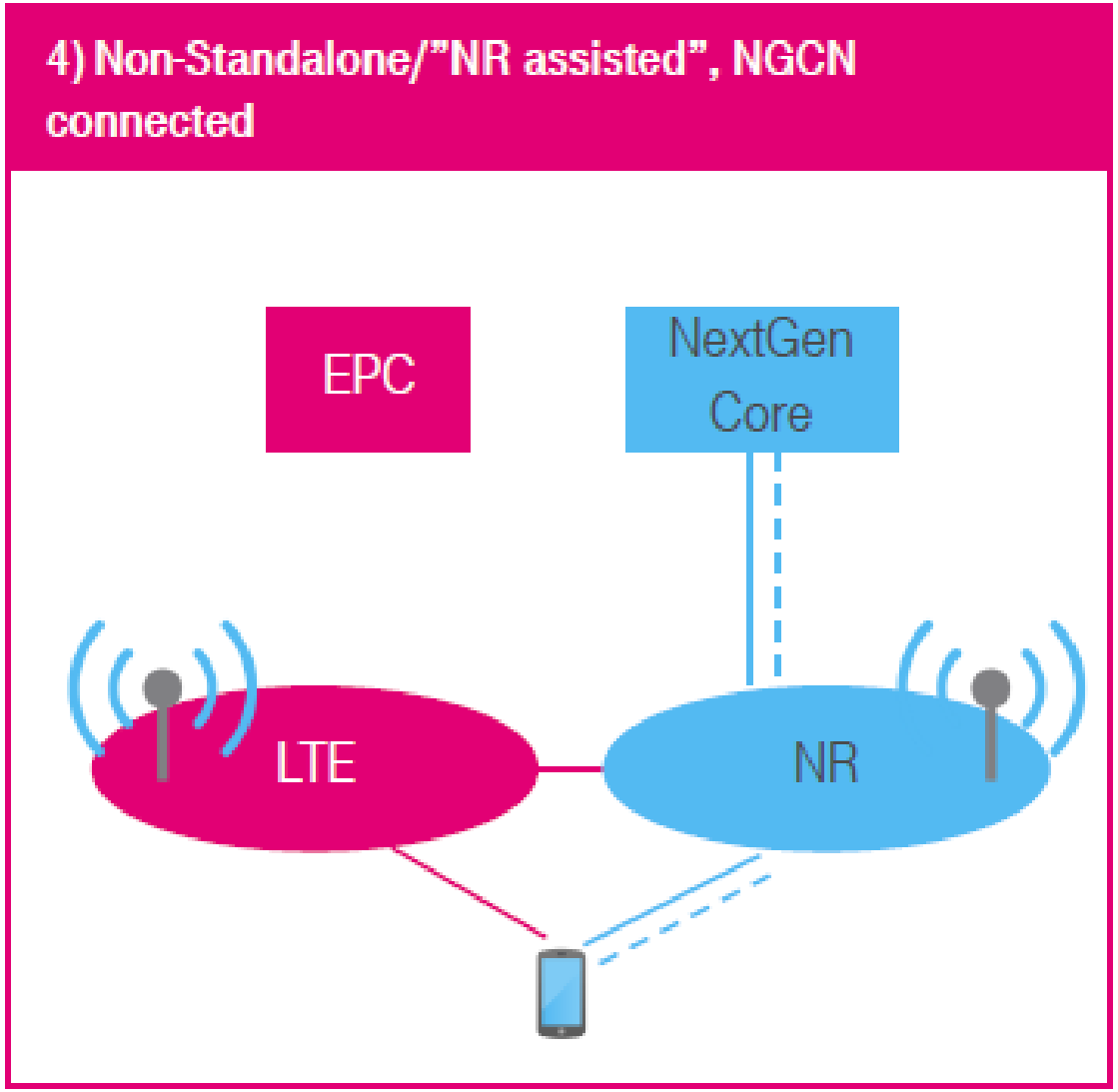

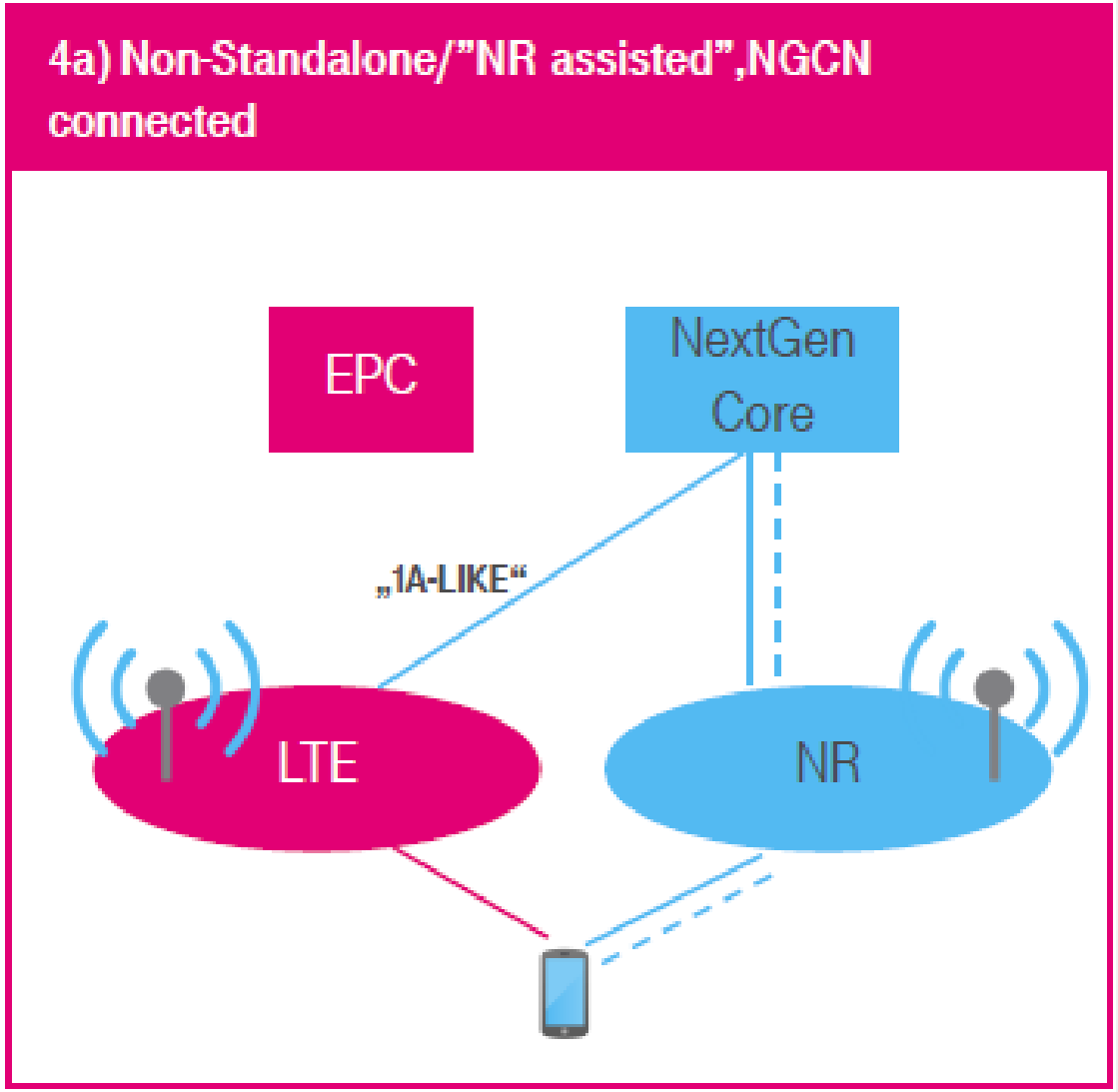

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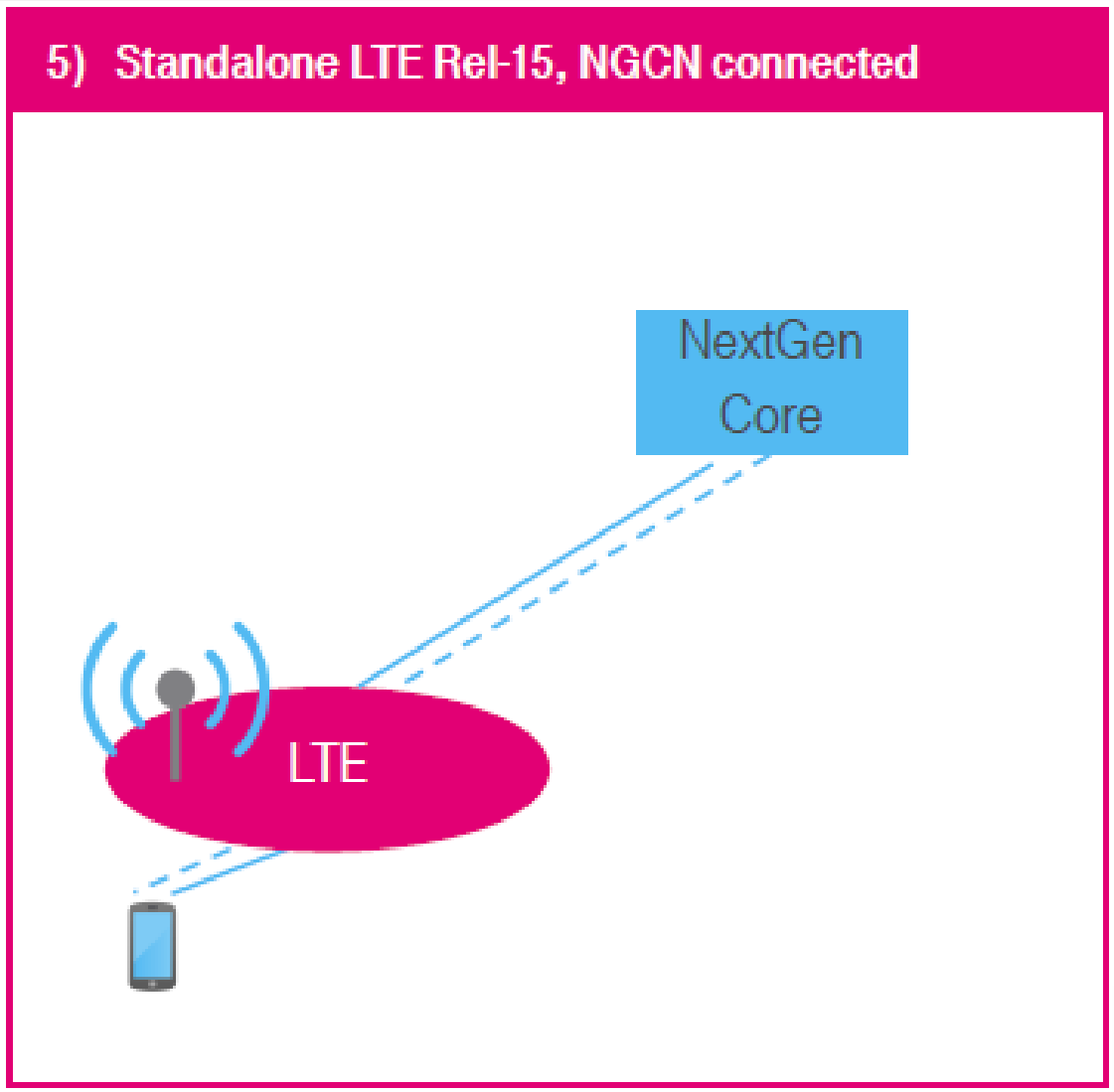

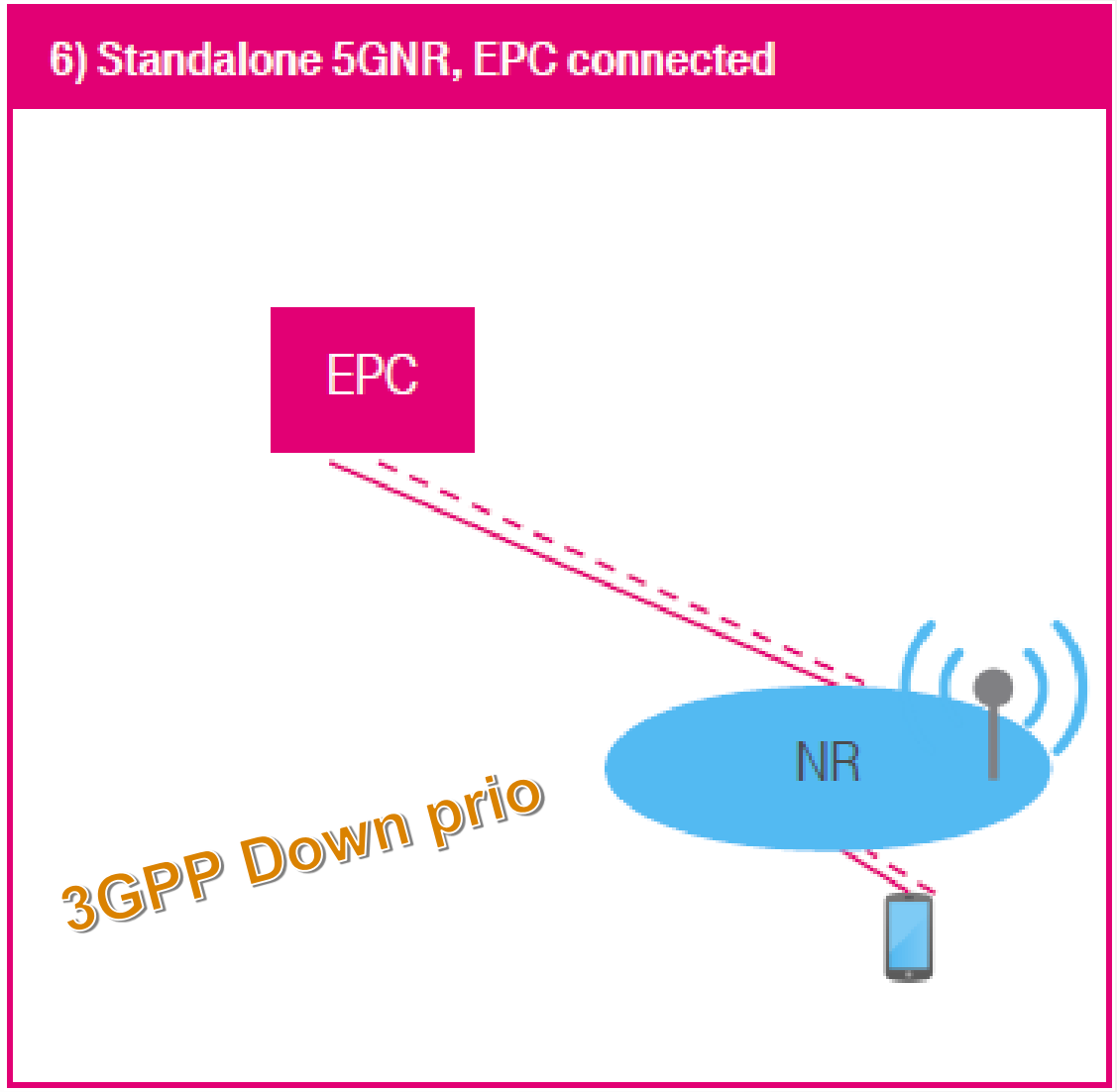

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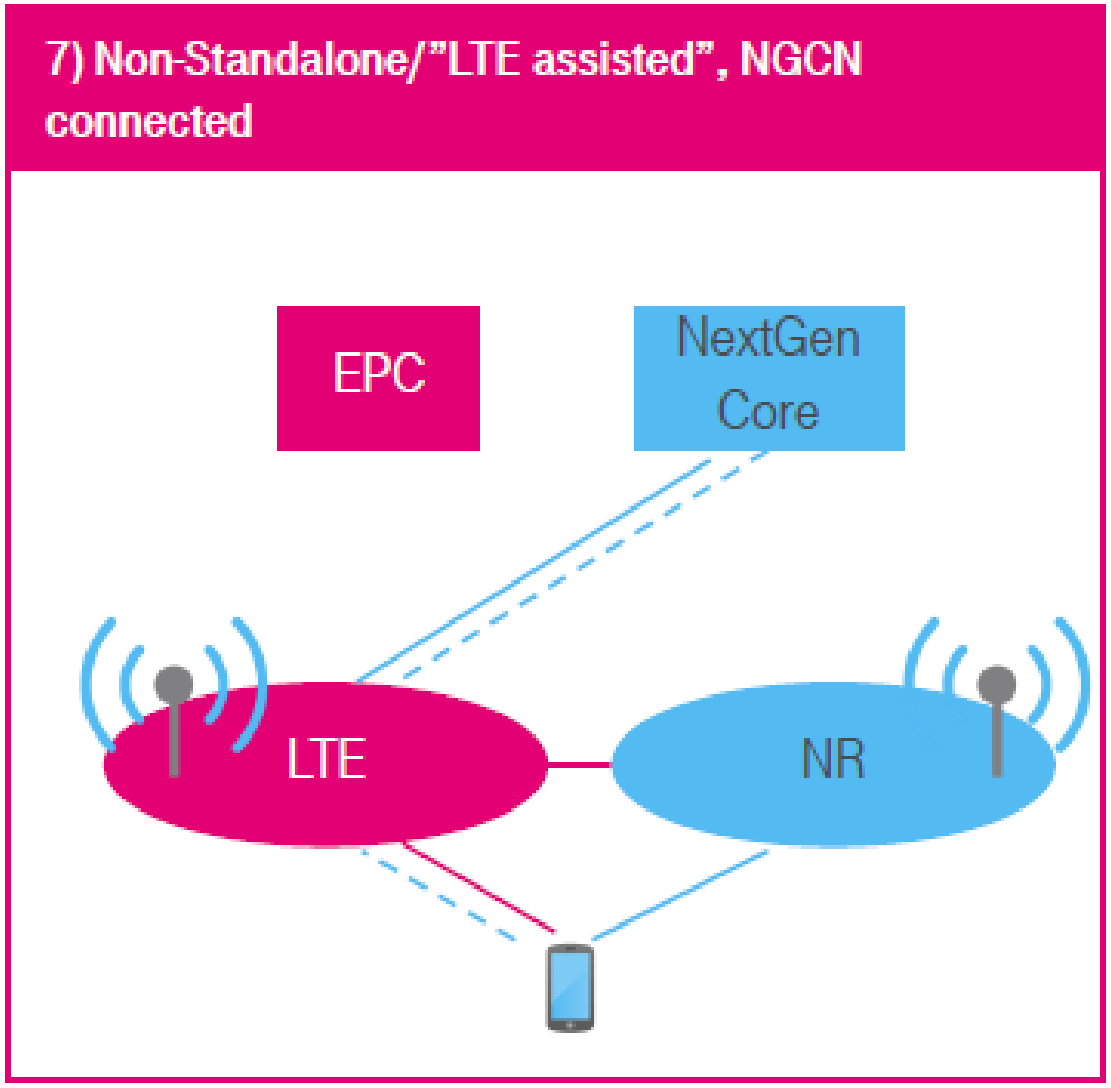

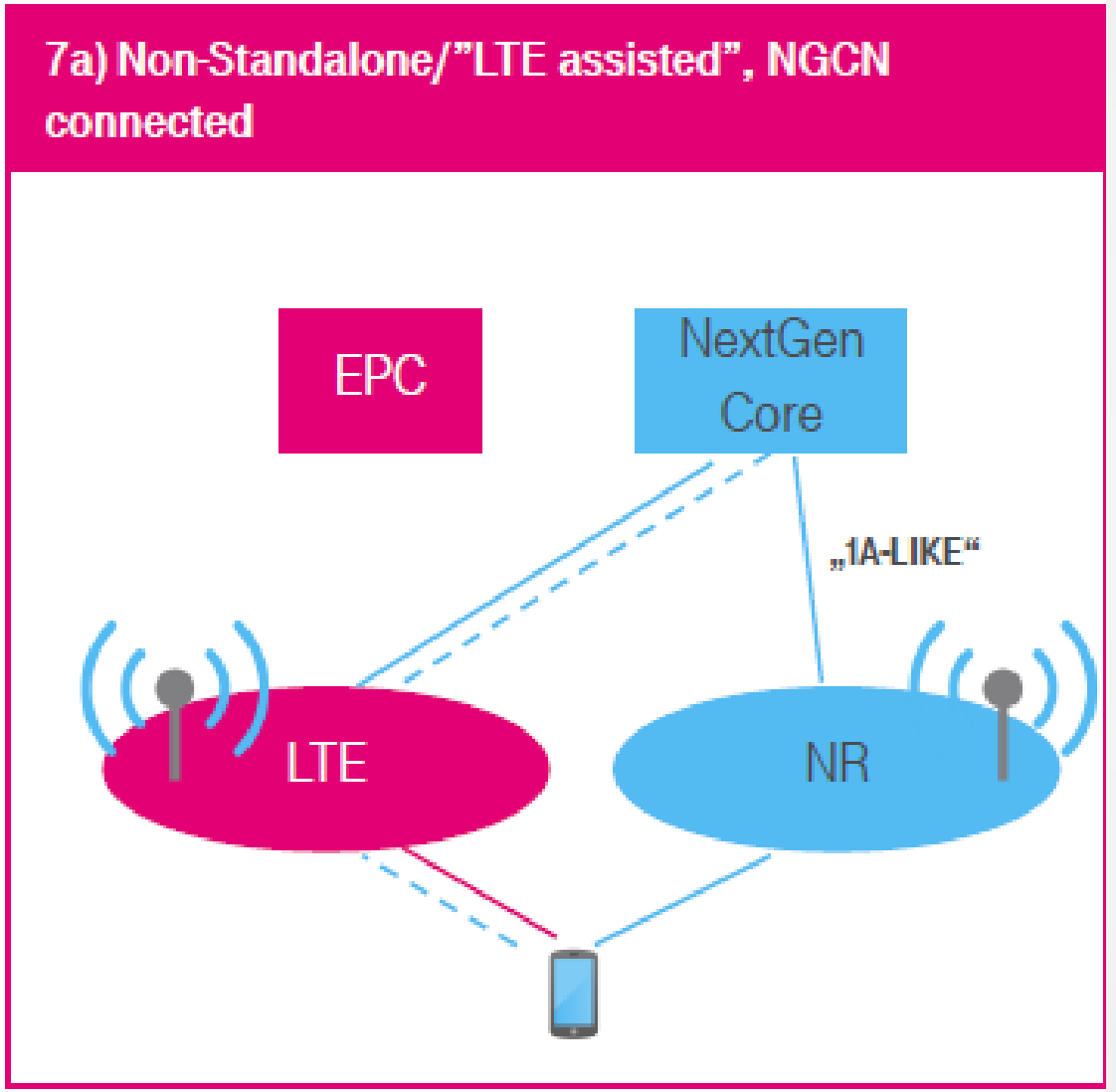

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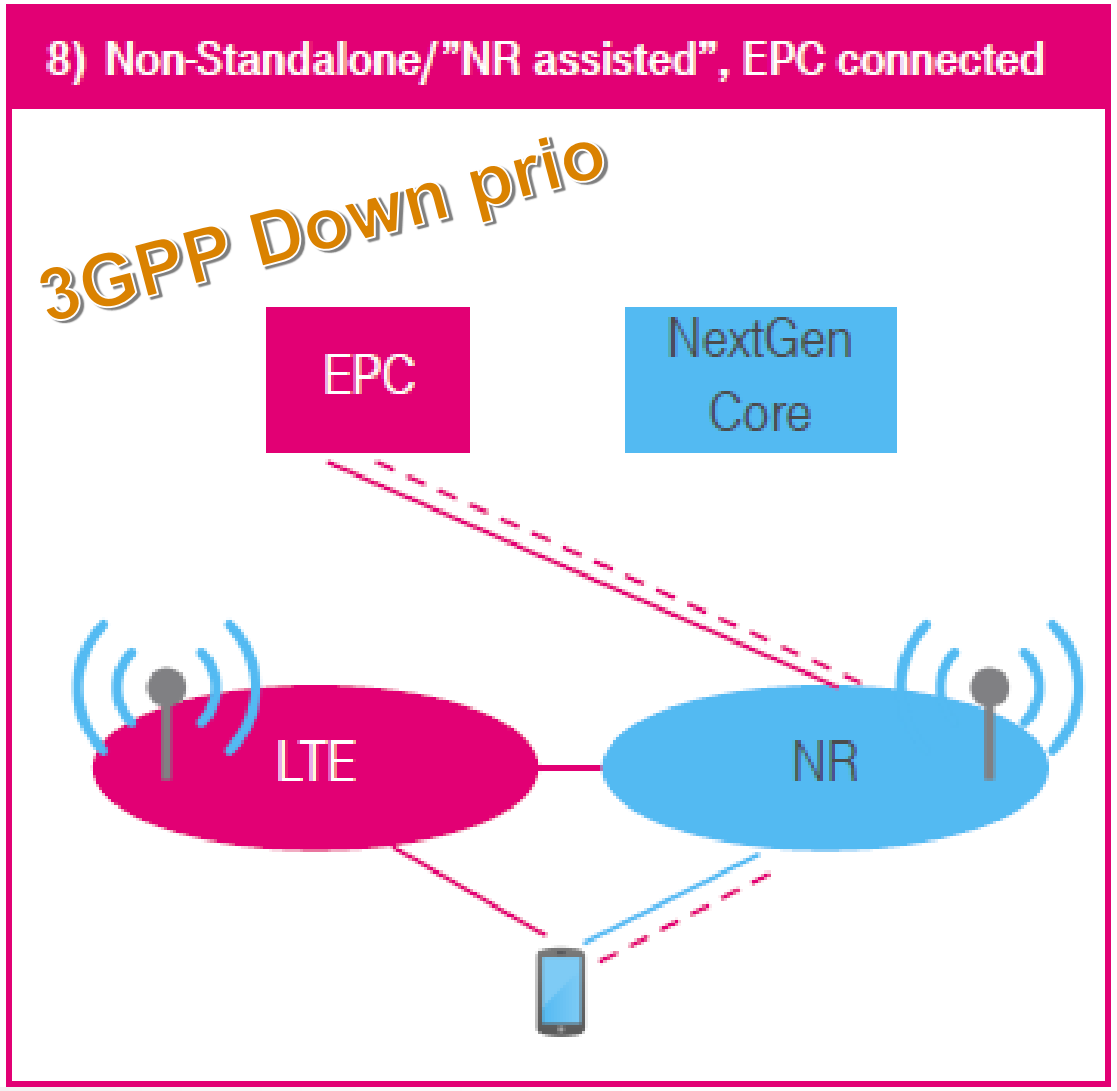
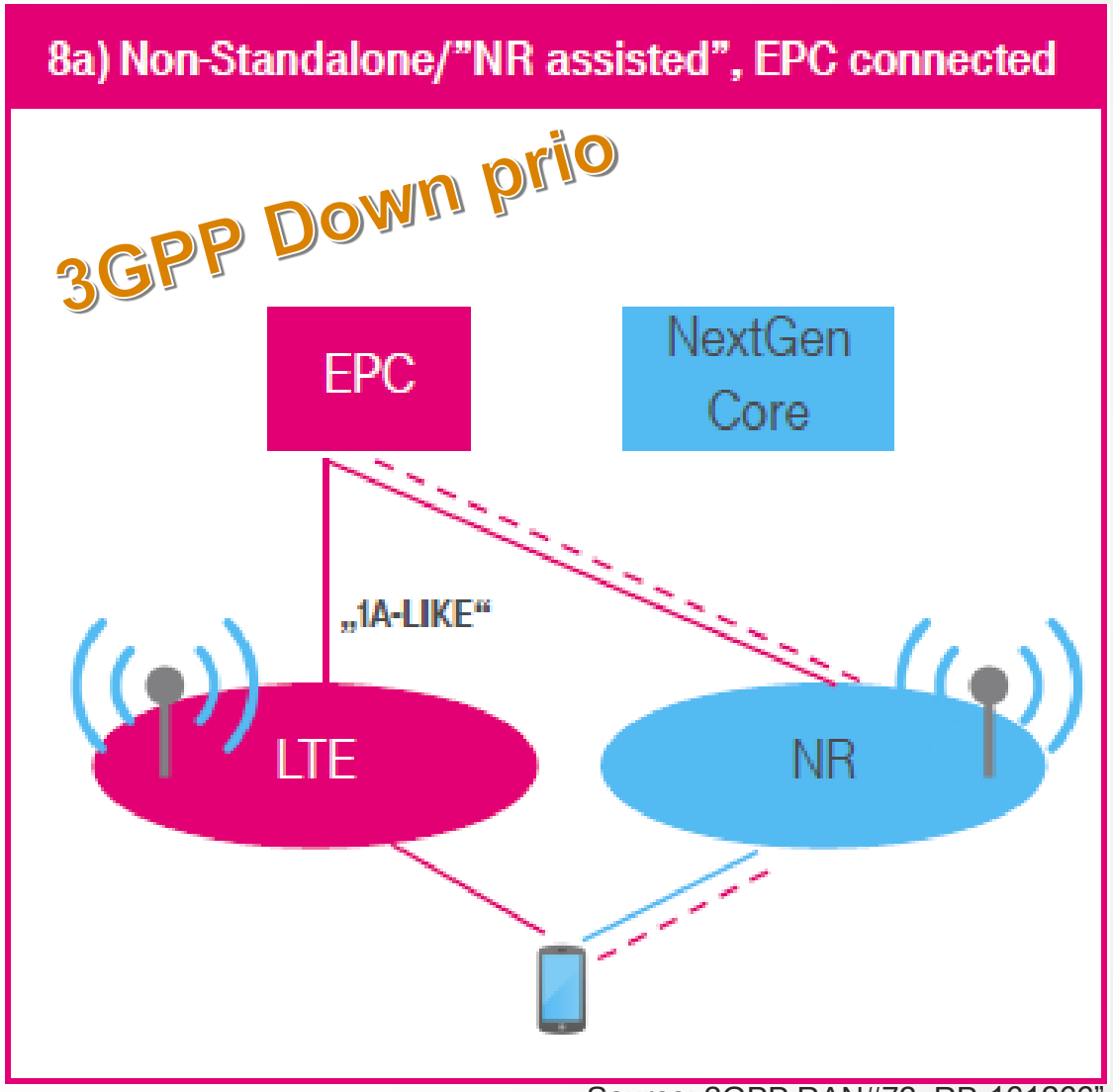
Dual Connectivity options





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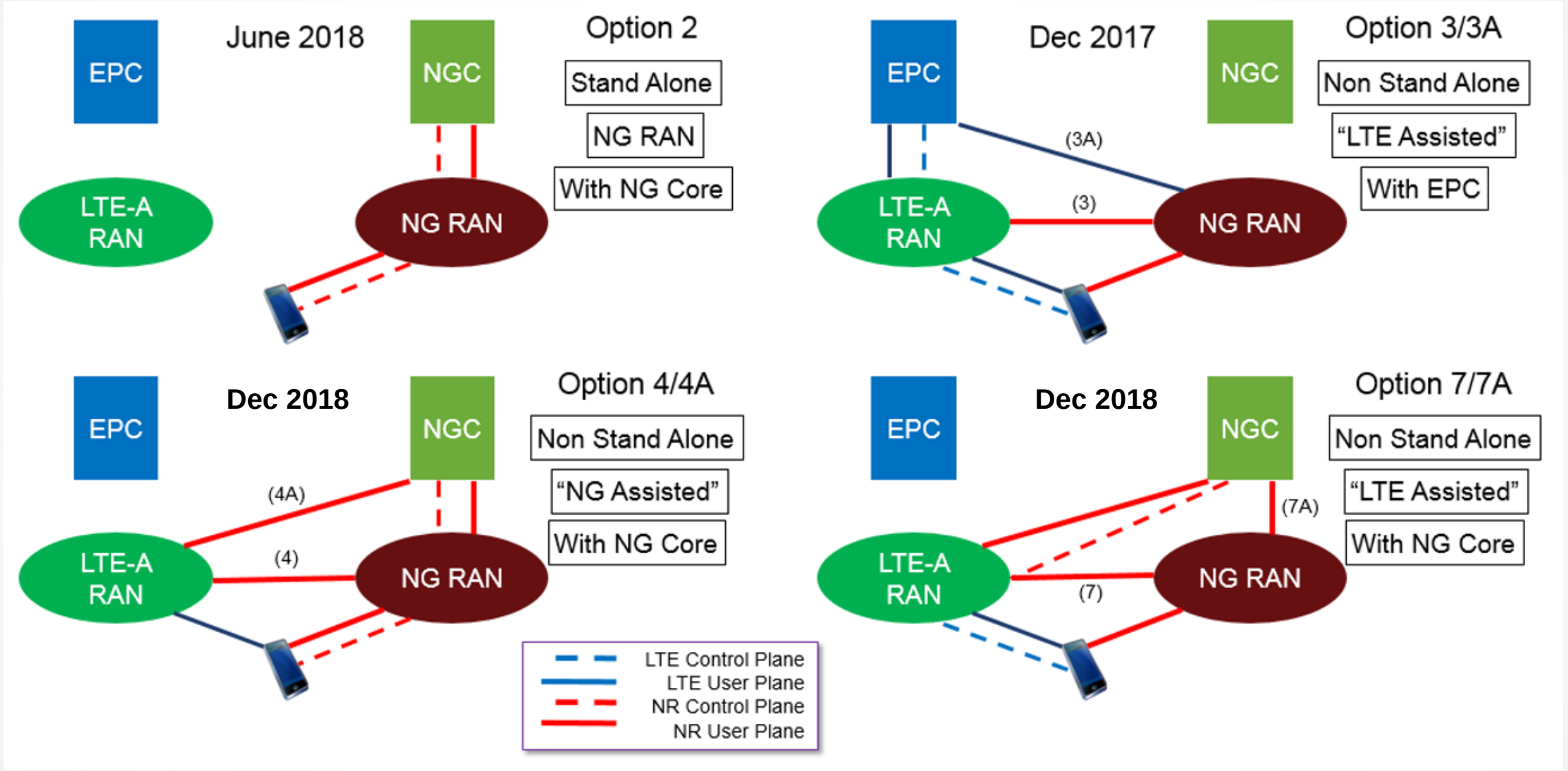
3GPP Rel 15 architecture priorities

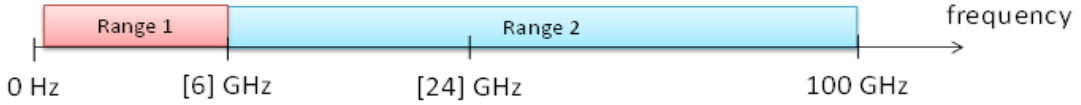


5G Testability Updates

3GPP Context

5G NR SPECIFICATIONS: CONDUCTED VS RADIATED

Range 1: Conducted (OTA is not precluded)
Range 2: Only OTA



According to 3GPP 38.803:

RAN4 UE specs	Spec title	Estimated approval date	Comments
38.101-1	NR; User Equipment (UE) radio transmission and reception Technical Specification for NR **range 1** for UE RF requirements	TSG-RAN #78 **(Dec'17)**	Rapporteur; Vintola Ville vvintola@QTI.QUALCOMM.COM **Core part**
38.101-2	NR; User Equipment (UE) radio transmission and reception Technical Specification for NR **range 2** for UE RF requirements	TSG-RAN #78 **(Dec'17)**	Rapporteur; Vintola Ville vvintola@QTI.QUALCOMM.COM **Core part**
38.101-3	NR; User Equipment (UE) radio transmission and reception Technical Specification for NR **interworking between NR range1 + NR range2** and **between NR and LTE** for UE RF requirements	TSG-RAN #78 **(Dec'17)**	Rapporteur; Vintola Ville vvintola@QTI.QUALCOMM.COM **Core part**
38.133	NR; Requirements for support of radio resource management	TSG-RAN #78 **(Dec'17)**	Rapporteur; Yang Tang yang.tang@INTEL.COM **Core part**
38.101-4	NR; User Equipment (UE) performance requirements	TSG-RAN #82 **(Dec'18)**	Rapporteur; TBD **Performance part**
38.133	NR; Requirements for support of radio resource management	TSG-RAN #82 **(Dec'18)**	Rapporteur; TBD **Performance part**

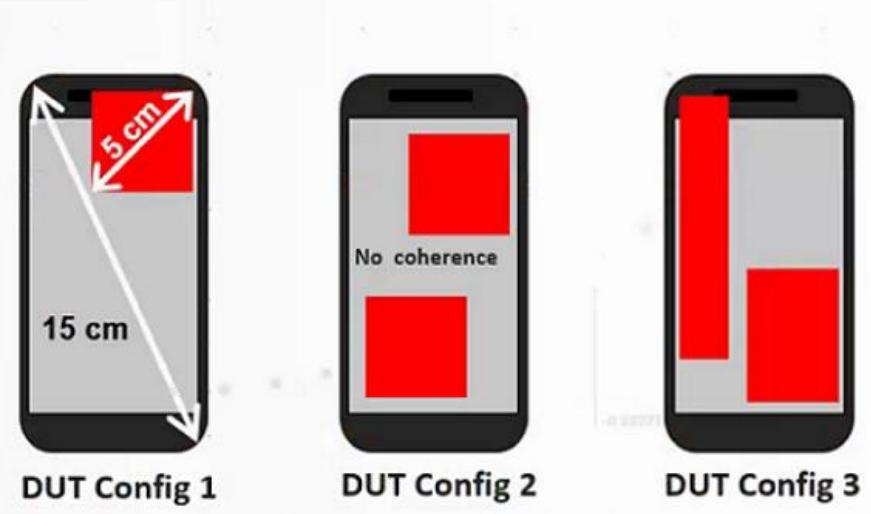
Mode	Frequency ranges involved	LTE connections	FR1 connections	FR2 connections
SA	FR1	--	Conducted-calibrated	--
SA	FR2	--	--	Radiated-calibrated
SA	FR1 (Pcell) + FR2	--	Radiated --not calibrated (*)	Radiated calibrated
NSA	LTE + FR1	Conducted-calibrated	Conducted-calibrated	--
NSA	LTE + FR2	Radiated --not calibrated (*)		Radiated calibrated
NSA	LTE + FR1 (Pcell) + FR2	Radiated --not calibrated (*)	Radiated --not calibrated (*)	Radiated calibrated

(*) When measuring FR2.
No FR1/LTE simultaneous measurements with FR2.
FR1 and LTE tested without FR2
References: R4-1803261, R4-1801587

RF measurement set-up

3GPP DEFINED DUT ANTENNA CONFIGURATIONS

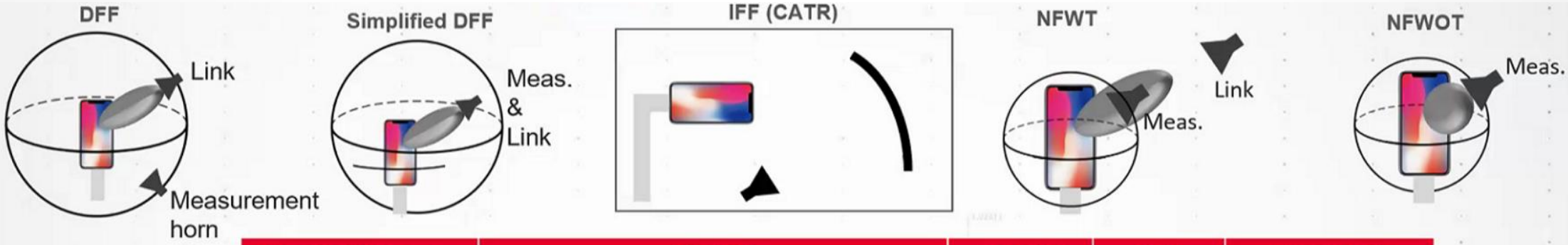
- DUT Antenna Configuration can be chosen by an optional declaration from a manufacturer



DUT Antenna Configuration	Description
Config 1	Maximum one antenna panel with D ≤ 5 cm active at any one time
Config 2	More than one antenna panel D ≤ 5 cm without phase coherence between panels active at any one time
Config 3	Any phase coherent antenna panel of any size (e.g. sparse array)

RF measurement set-up

PERMITTED OTA TEST SYSTEMS

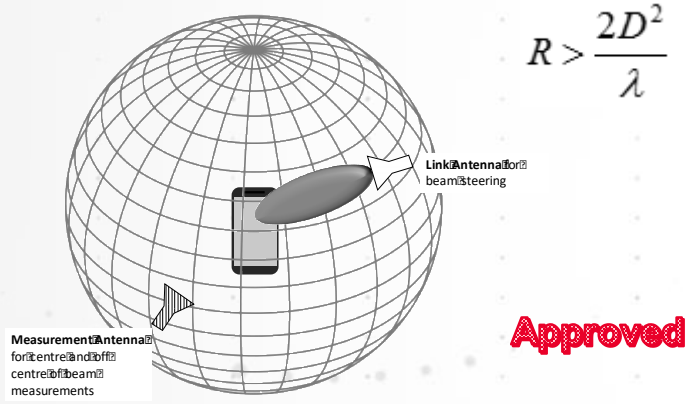


Permitted Systems	UE RF		DEMOD	RRM	Protocol Sig
	Tx	Rx			
Direct Far-Field (DFF)	Yes (DUT config 1, 2)	Yes (DUT config 1 DUT config 2: no MU defined)	Yes	Yes (1 and 2 AoAs)	Yes
Simplified DFF	Yes (DUT config 1, 2)	Yes (DUT config 1 DUT config 2: no MU defined)	Yes	Yes (1AoA)	Yes (single cell TCs)
Indirect Far-Field (IFF)	Yes (DUT config 1, 2, 3)	Yes (DUT config 1, 2, 3)	Yes	Yes (1 AoA)	Yes (single TCs
Near Field With Transform (NFWT)	Partially	No	No	No	No
Near Field Without Transform (NFWOT)	No	No	Yes	No	Not precluded (single cell TCs)

RF measurement set-up

RF PARAMETRICS: MEASUREMENT SET-UPS DESCRIPTION

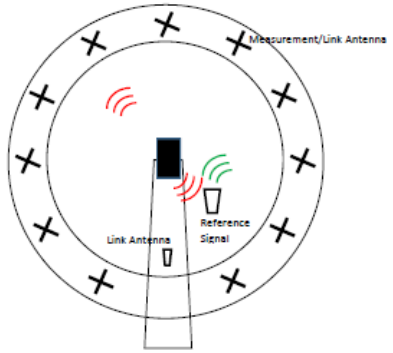
DIRECT FAR FIELD (R4-1803554)



$$R > \frac{2D^2}{\lambda}$$

Approved

NEAR FIELD TO FAR FIELD TRANSFORM (R4-1805062)



Approved

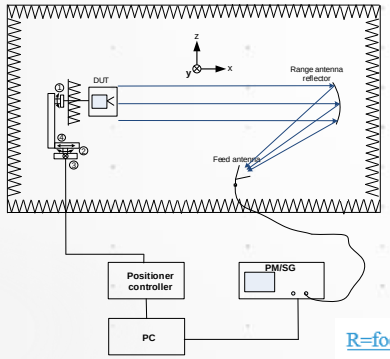
REVERBERATION CHAMBER (R4-1803412)

Not available

Not accepted so far

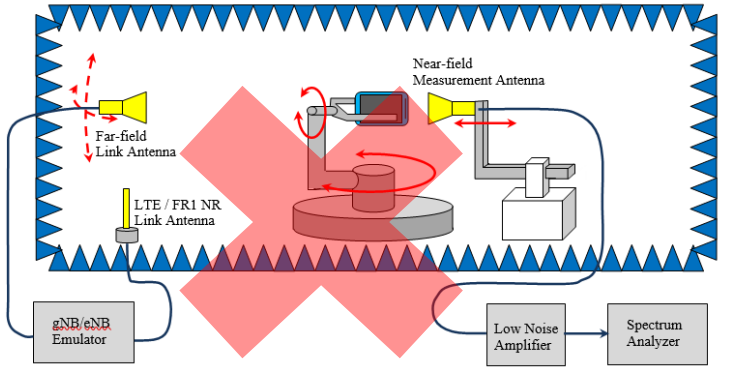
INDIRECT FAR FIELD (R4-1803575)

Approved



R=focal length = 3.5*size of reflector = 3.5*(2*D)

NEAR FIELD WITHOUT FAR FIELD TRANSFORM (R4-1805896)



Not accepted so far

RRM Testability agreement (R4-1710028)

1. Only RRM static geometry scenarios to be prioritized so far, i.e. in terms of RRM testing complexity scenarios:
    1. Scenario 1: 1 NR TRxP + AWGN + Static AoA
    2. Scenario 3: 1 NR TRxP + Fading + Static AoA
    3. Scenario 5: 2 NR TRxPs + AWGN + Static AoA
    4. Scenario 7: 2 NR TRxPs + Fading + Static AoA

Impact:
Beam steering capability not tested

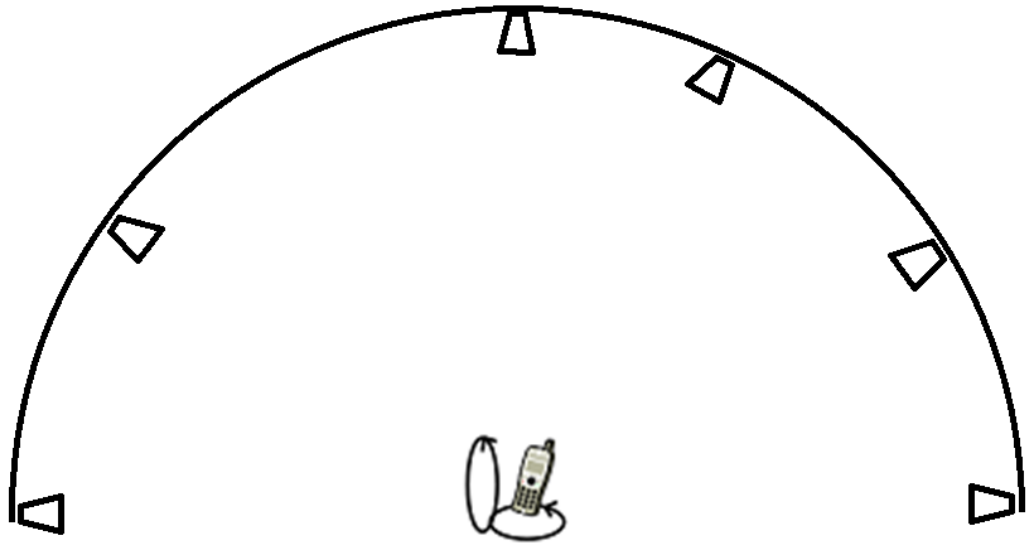
2. Fading i.e. emulation of the propagation channel for RRM is under discussion in another WF.
   Its appliance to 1 or 2 TRxPs affects directly the baseline setup.

Still under discussion as shown in section 2.2 in R4-1800021

RRM baseline measurement set-up

R4-1803532, R4-1808402, R4-1808405

- OTA link, LTE radiated link for NSA (not calibrated). Positioning system.
- Rel 15 testing scope: Up to **2 NR transmission reception points** TRxPs are emulated. (max num of simultaneously active AoA)
- Relative angular relationships between the active AoA: **30º, 60º, 90º, 120º, 150º and 180º**



5G Protocol Conformance Test Cases

TEST CASE ESTIMATES

- Breakdown below based on the latest available RAN5 work plans and estimates.
- Covers Release-15 only. Further 5G PCT test cases will also be defined in later 3GPP releases.
- Test case numbers below are subject to ongoing revisions by RAN5.

<table>
<tr><th>5GS Rel-15</th><th>TCs #</th><th>Timescale for TTCN development</th><th>Comments</th></tr>
<tr><td>NSA option 3</td><td>112</td><td>2018: 90%
2019: 10%</td><td>Test case breakdown:
<table>
<tr><th>Layer</th><th>Phase 1</th><th>Phase 2</th><th>Phase 3</th><th>Phase x</th></tr>
<tr><td>MAC</td><td>28</td><td>9</td><td></td><td rowspan="5">May contain TCs for NR L1/L2 flexibility testing</td></tr>
<tr><td>RLC</td><td>17</td><td></td><td></td></tr>
<tr><td>PDCP</td><td>14</td><td></td><td></td></tr>
<tr><td>RRC</td><td>12</td><td>20</td><td>9</td></tr>
<tr><td>NAS</td><td>3</td><td></td><td></td></tr>
<tr><td>Total</td><td>74</td><td>29</td><td>9</td><td></td></tr>
</table></td></tr>
<tr><td>SA options 2,5</td><td>~250</td><td>2018: 25%
2019: 75%</td><td>Includes all layers of option3 + IdleMode, NR SDAP/RRC, 5GC, inter-RAT with 4G.</td></tr>
<tr><td>NSA options 4,7</td><td>~75</td><td>2019: 100%</td><td>Option4: extension of option2, test scope limited to DC.
Option7: extension of option5, test scope limited to DC.</td></tr>
<tr><td>IMS</td><td>~75</td><td>2018: 20%
2019: 80%</td><td>Voice, video, SMS, emergency, codecs…</td></tr>
<tr><td>TOTAL:</td><td>~512</td><td></td><td></td></tr>
</table>

GCF 5G Status

GCF

Dec 2017: GCF approved the creation of 5G work items (SG#73)

Mar 2018: 5G work item structure agreed (CAG#53bis)

Apr 2018: Umbrella work items created (CAG#54)

Jul 2018: Sub-work items, with bands/ test case lists, agreed (CAG#55)

Oct 2018: Target for first 5G test case validations (CAG#56). Likely to be delayed due to need to move to Sep '18 ASN.1

Jan 2019: Target for activation of 5G certification (CAG#57)

Umbrella Work Item	Sub Work Items
WI-500: 5G RF	WI-500_NR-nx WI-500_EUTRA-5GC-x WI-500_EN-DC_x_ny WI-500_NGEN-DC_x_ny
WI-501: 5G RRM	WI-501_NR-nx WI-501_EUTRA-5GC-x WI-501_EN-DC_x_ny WI-501_NGEN-DC_x_ny
WI-502: 5G De-Mod/CSI	WI-502_NR-nx WI-502_EUTRA-5GC-x WI-502_EN-DC_x_ny WI-502_NGEN-DC_x_ny
WI-503: 5G RAN Protocol	WI-503_NR-nx ***(opt 2)*** WI-503_EUTRA-5GC-x ***(opt 5)*** WI-503_EN-DC_x_ny ***(opt 3)*** WI-503_NGEN-DC_x_ny ***(opt 7)***
WI-504: 5G NAS Protocol	WI-504_NR-nx WI-504_EUTRA-5GC-x WI-504_EN-DC_x_ny WI-504_NGEN-DC_x_ny
WI-505: IMS Protocol	
WI-506: 5G Positioning	

Keysight 5G Testing Solutions

5G Device E2E Workflow Solutions

FIRST-TO-MARKET WITH 5G NR-READY NETWORK EMULATION SOLUTIONS

5G Interactive R&D Solutions

- 5G Protocol R&D Toolset
- 5G RF DVT Toolset
- 5G Functional KPI Toolset

5G Device Acceptance Solutions

- 5G Protocol Conformance Toolset
- 5G RF/ RRM Conformance Toolset
- 5G Carrier Acceptance Toolset

5G MFG Solutions

- 5G Manufacturing

Network Emulator

Channel Emulator

mmWave OTA Solutions

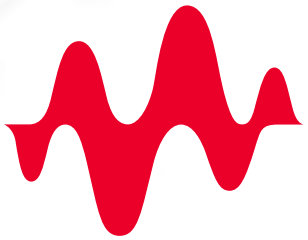
5G Network Emulator Solutions – building blocks

UXM 5G (E7515B)

UXM 5G Wireless Test Platform (E7515B)

- <6GHz Frequency range
- Scalable bandwidth 8Tx/4Rx @800MHz, 4Tx/2Rx @1600MHz
- Integrated RFIO + Internal fading
- Support for RF, IF, Host and BBIQ interfaces (slow and full rate)
- Support for 10GbE connectivity


THANK YOU FOR LISTENING
ANY QUESTIONS?



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