5G NR and Validation Solutions

Keysight Technologies **2019.10**

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KEYSIGHT TECHNOLOGIES

5G Scenarios and Use Cases

BROAD RANGE OF NEW SERVICES AND PARADIGMS

Amazingly Fast	Great Service in a Crowd	Best Experience Follows You	Ubiquitous Things Communicating	Real-time & Reliable Communications

eMBB

Mobile Broadband Access

- All data, all the time
- 2 billion people on social media

mMTC

Massive Machine Communication

- 30 billion ‘things’ connected
- Low cost, low energy

URLLC

Mission-Critical Machine Communication

- Ultra-high reliability
- Ultra-low latency

5G Specifications

ALIGNED WITH IMT VISION

- IMT 2020 are still defining specs
- IMT: International Mobile Telecommunications Initiative (by ITU)

Phase 1 – mid 2018

- Focus on **eMBB** and low latency aspects
- **Minimized changes to core architecture** (LTE-EPC) – **NSA** operation initially
- 5G RAT - focus on “conventional” frequency channels

Phase 2 – mid 2020

- Focus on **mMTC** and **URLLC**
- Novel layers and architecture to allow full 5G potential (vehicular and multicast services)
- “mmWave” 28, 37, 39 GHz channels and unlicensed spectrum

Rel-12 LTE-A
Rel-13
Rel-14
Rel-15 5G Phase 1
Rel-16 5G Phase 2

2015 2016 2017 2018 2020

5G New Radio

AT A GLANCE – KEY DISTINCTIVE FEATURES - 1

- 2 frequency ranges:
  - **FR1 (410 MHz – 7.125 GHz)**
    - Bands numbered from 1 to 255
    - *No longer can be commonly referred to as sub-6 GHz!*
  - **FR2 (24.250 - 52.600 GHz)** → *Soon to be extended to* ***114.25 GHz***
    - Bands numbered from 257 to 511
    - Commonly referred to as mmWave
  - Channel bandwidths up to 400 MHz for single component carrier

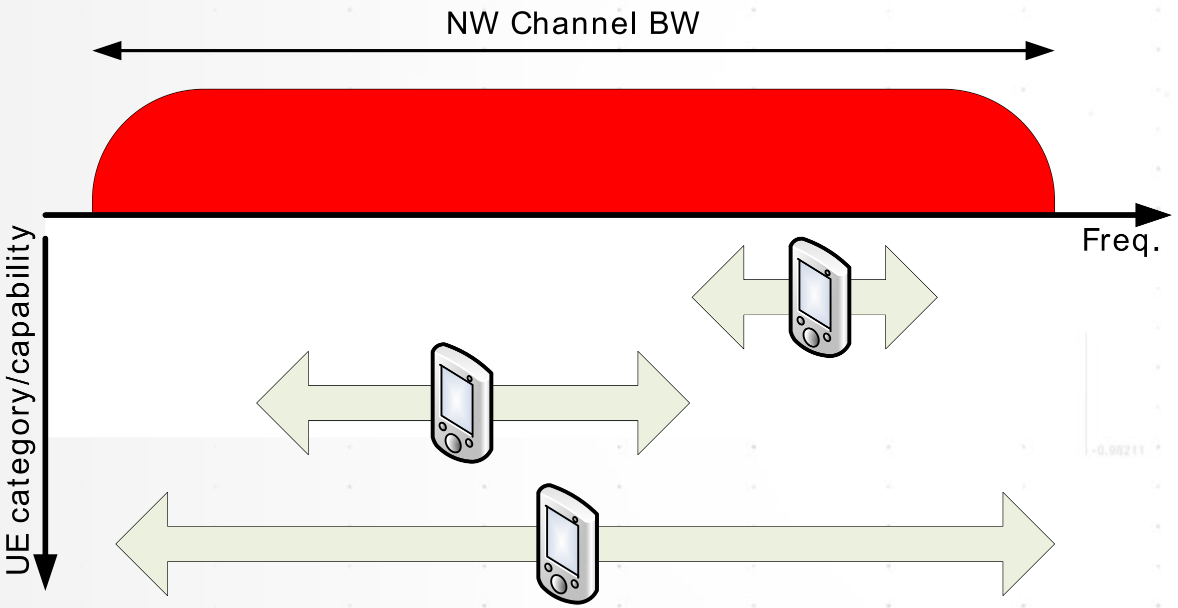
The principle of extending the upper limit of FR1 from 6GHz to 7.125GHz was agreed in RAN #82

μ	SCS (kHz)	5 MHz	10 MHz	15 MHz	20 MHz	25 MHz	30 MHz	40 MHz	50 MHz	60 MHz	70 MHz	80 MHz	90 MHz	100 MHz
0	**15**	25	52	79	106	133	160	216	270	N/A	N/A	N/A	N/A	N/A
BW [MHz]		4.5	9.4	14.2	19.1	23.9	28.8	38.9	48.6					
GB [KHz]		242.5	312.5	382.5	452.5	522.5	592.5	552.5	692.5					
1	**30**	11	24	38	51	65	78	106	133	162	189	217	245	273
BW [MHz]		4	8.6	13.7	18.4	23.4	28.1	38.2	47.9	58.3	68	78.1	88.2	98.3
GB [KHz]		505	665	645	805	785	945	905	1045	825	965	925	885	845
2	**60**	N/A	11	18	24	31	38	51	65	79	93	107	121	135
BW [MHz]			7.9	13	17.3	22.3	27.4	36.7	46.8	56.9	67	77	87.1	97.2
GB [KHz]			1010	990	1330	1310	1290	1610	1570	1530	1490	1450	1410	1370

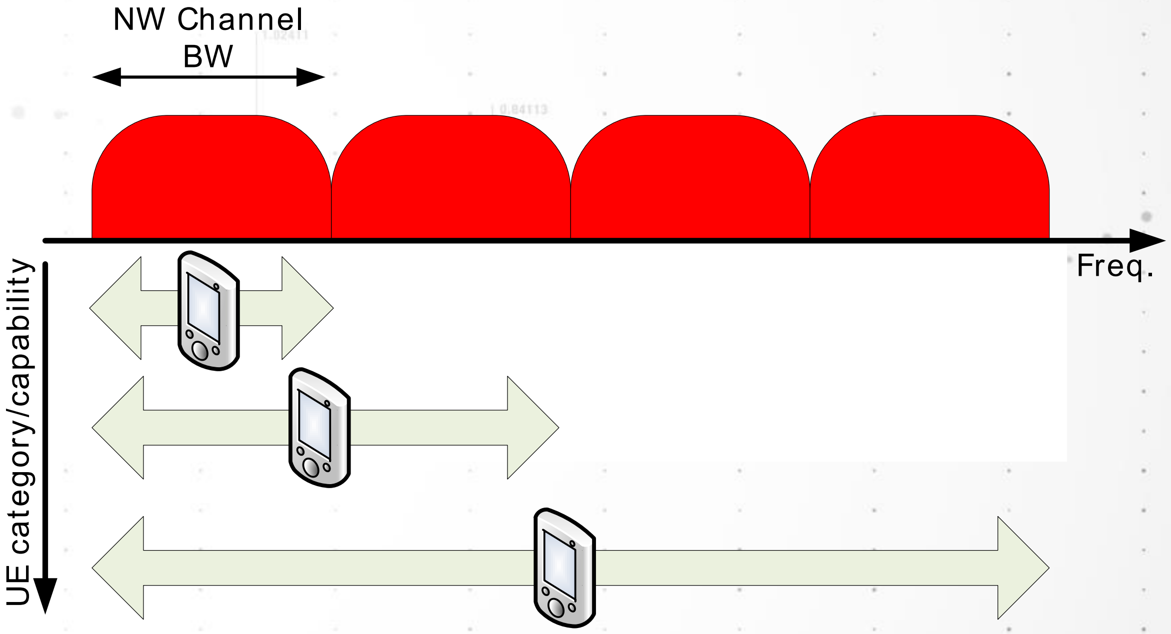
μ	SCS (kHz)	50 MHz	100 MHz	200 MHz	400 MHz
2	**60**	66	132	264	N/A
BW [MHz]		47.5	95	190.1	
GB [KHz]		1210	2450	4930	
3	**120**	32	66	132	264
BW [MHz]		46.1	95	190.1	380.2
GB [KHz]		1900	2420	4900	9860

Single-Carrier and Multi-Carrier Operation

- Maximum single-CC bandwidth is ***400 MHz***
- Maximum number of CCs is ***8***



Single-Carrier Operation



Multi-Carrier Operation

Bandwidth Part

CONTIGUOUS PHYSICAL RESOURCE BLOCKS (PRBS)

- An ***Initial Bandwidth Part*** is signaled by PBCH
- It contains CORESET (Control Resource Set) and PDSCH
- The bandwidth part may or may not contain (Beamforming) SS/PBCH block
- Reserved resources can be configured within the bandwidth part
- ***One or multiple bandwidth part configurations for each component carrier*** can be semi-statically signaled to a UE
  - ***Only one BWP in DL and one in UL is active at a given time***

- Other configuration parameters include:
  - ***Numerology***: CP type, subcarrier spacing
  - ***Frequency location***: the offset between BWP and a reference point within cell BW
  - ***Bandwidth size:*** in terms of PRBs

5G New Radio

AT A GLANCE – KEY DISTINCTIVE FEATURES - 2

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- ***Scalability required for different use cases/frequency bands***
  - ***Scalable numerology*** - sub-frame structure and component carrier bandwidth
  - Introduction of ***mini-slots*** for low latency

5G New Radio

AT A GLANCE – KEY DISTINCTIVE FEATURES – 2

- Scalability required for different use cases/frequency bands
  - Scalable numerology - sub-frame structure and component carrier bandwidth
  - Introduction of mini-slots for low latency

FR1 Operation

Initial Access: μ = 0, 1 — Data: μ = 0, 1, 2

μ	$\Delta f = 2^{\mu} \cdot 15$ kHz	Cyclic Prefix	$N_{RB}^{max,\mu}$	$N_{slot}^{subframe,\mu}$
0	15 kHz	Normal	275	1
1	30 kHz	Normal	275	2
2	60 kHz	Normal, Extended	275	4

FR2 Operation

Initial Access: μ = 3, 4 — Data: μ = 2, 3

μ	$\Delta f = 2^{\mu} \cdot 15$ kHz	Cyclic Prefix	$N_{RB}^{max,\mu}$	$N_{slot}^{subframe,\mu}$
2	60 kHz	Normal, Extended	275	4
3	120 kHz	Normal	275	8
4	240 kHz	Normal	138	16
5	480 kHz	Normal	69	32

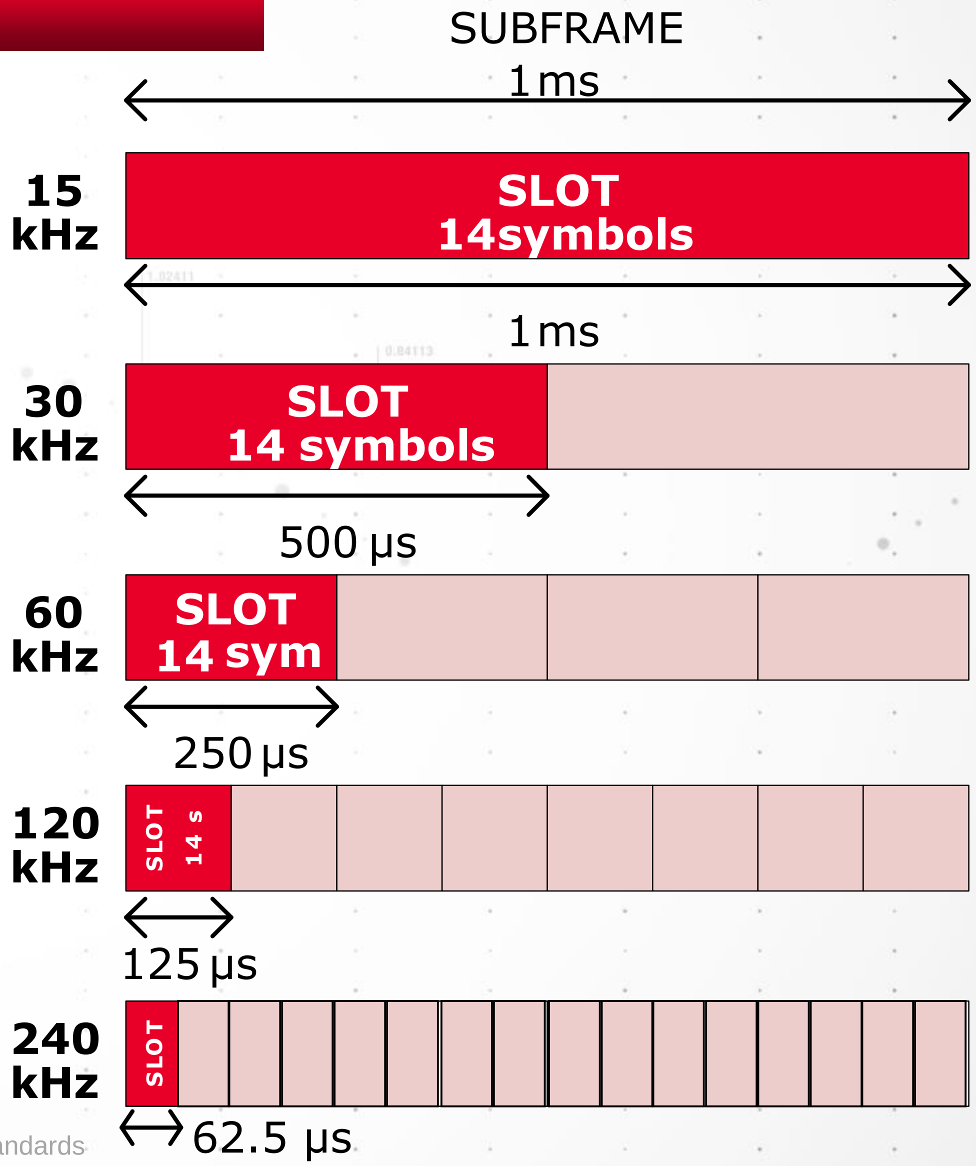
Keysight World: 5G NR Standards

Frame Structure

FRAME STRUCTURE & NUMEROLOGY

Slot structure is flexible to provide for better spectrum utilization

- **SCS**: 15 kHz*2n
- **Frame: 10 ms**
- Subframe: Reference period of 1 ms
- **Slot (slot based scheduling)**
  - **14 OFDM symbols**, or 12 with extended CP
  - One possible scheduling unit
  - Slot length scales with the subcarrier spacing
- **Mini-Slot (non-slot based scheduling)** NEW
  - 7, 4 or 2 OFDM symbols, can start immediately
  - Minimum scheduling unit



Slot Usage

FDD AND TDD SLOTS, AND A MIX OF

Slot Format Indication (SFI) informs the UE of the current format (56 formats defined)

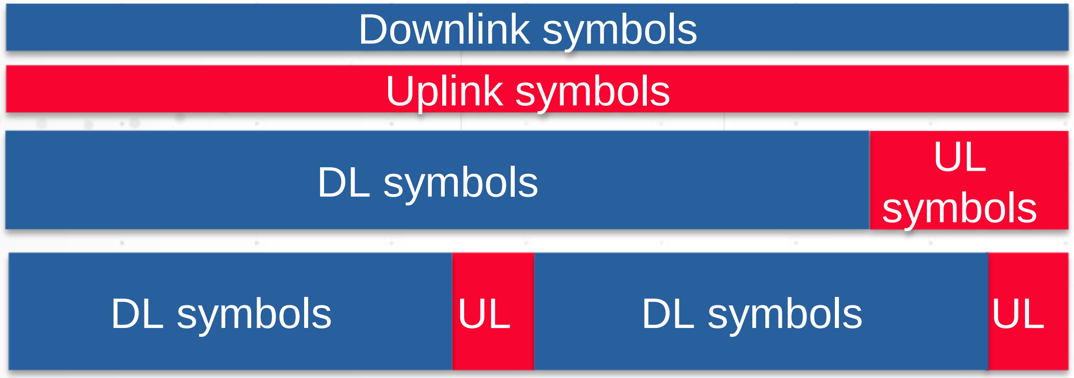
- Downlink only (Slot Format 0, used in FDD)
- Uplink only (Slot Format 1, Used in FDD)
- Flexible: Downlink and Uplink (static, semi-static (RRC) or dynamically scheduled (DCI))

Examples:

FDD at 700 MHz

TDD at 3 GHz

TDD at 28 GHz



Not tied to the frame structure

Release 15 86 3GPP TS 38.213 V15.5.0 (2019-03)

Table 11.1.1-1: Slot formats for normal cyclic prefix

Format	Symbol number in a slot													
	0	1	2	3	4	5	6	7	8	9	10	11	12	13
0	D	D	D	D	D	D	D	D	D	D	D	D	D	D
1	U	U	U	U	U	U	U	U	U	U	U	U	U	U
2	F	F	F	F	F	F	F	F	F	F	F	F	F	F
3	D	D	D	D	D	D	D	D	D	D	D	D	D	F
4	D	D	D	D	D	D	D	D	D	D	D	D	F	F
5	D	D	D	D	D	D	D	D	D	D	D	F	F	F
6	D	D	D	D	D	D	D	D	D	D	F	F	F	F
7	D	D	D	D	D	D	D	D	D	F	F	F	F	F
8	F	F	F	F	F	F	F	F	F	F	F	F	F	U
9	F	F	F	F	F	F	F	F	F	F	F	F	U	U
10	F	U	U	U	U	U	U	U	U	U	U	U	U	U
11	F	F	U	U	U	U	U	U	U	U	U	U	U	U
12	F	F	F	U	U	U	U	U	U	U	U	U	U	U
13	F	F	F	F	U	U	U	U	U	U	U	U	U	U
......														
52	D	F	F	F	F	F	U	D	F	F	F	F	F	U
53	D	D	F	F	F	F	U	D	D	F	F	F	F	U
54	F	F	F	F	F	F	F	D	D	D	D	D	D	D
55	D	D	F	F	F	U	U	U	D	D	D	D	D	D
56 – 254	Reserved													
255	UE determines the slot format for the slot based on *TDD-UL-DL-ConfigurationCommon*, or *TDD-UL-DL-ConfigDedicated* and, if any, on detected DCI formats													

Reduced Latency – Comparation with LTE

LTE – Fixed FDD or TDD operation

5G NR – Self-contained Integrated Sub-frame

- Data is transmitted **preceded** by the grant for the acknowledgement: the entire process is complete within a single time transmission interval (TTI).
- TTI = # of symbols * symbol length

5G New Radio

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- Scalability required for different use cases/frequency bands
  - Scalable numerology - sub-frame structure and component carrier bandwidth
  - Introduction of mini-slots for low latency
- ***3D Beamforming antennas - MU-MIMO steerable on per UE basis, massive MIMO***

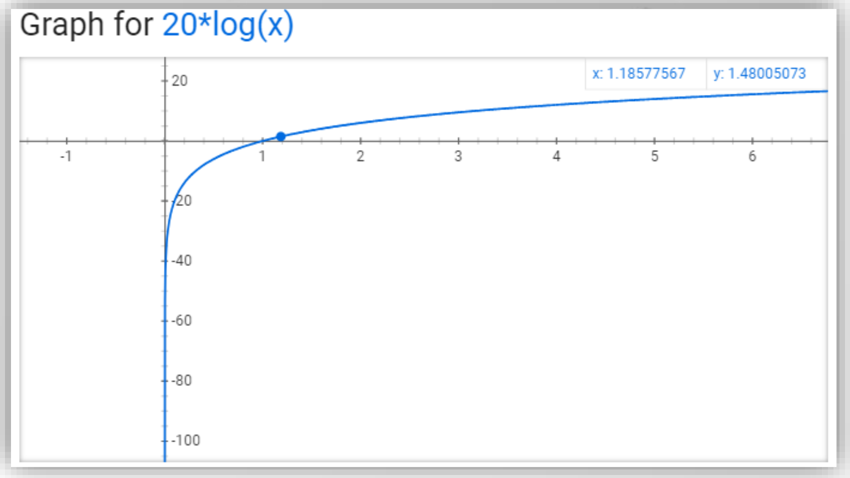
Moving to mmWave Change Everything

The plan to introduce cellular services in frequency bands >6 GHz is driving an **abrupt and unprecedented change** in how devices and systems have to be designed, operated and tested.

- To overcome these losses and provide a realistic link budget, it is necessary ***to use high gain antennas*** comprised of multiple elements at both ends of the link
- High gain antennas create narrow beam width signals
- **Radio propagation at mmWave is very different*: very sparse and spatially dynamic*,** unlike rich multipath with Rayleigh fading

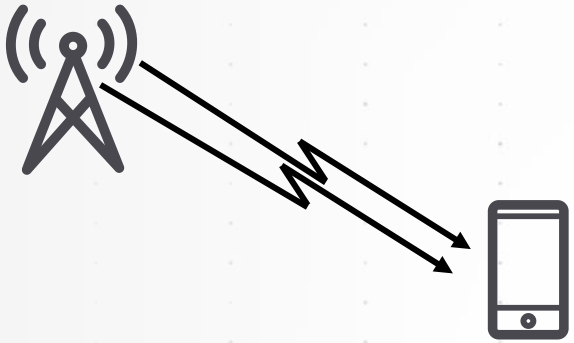
The Friis propagation equation predicts losses at mmWave frequencies:

$$P_r = P_t + G_t + G_r + 20\log_{10}\left(\frac{\lambda}{4\pi R}\right)$$

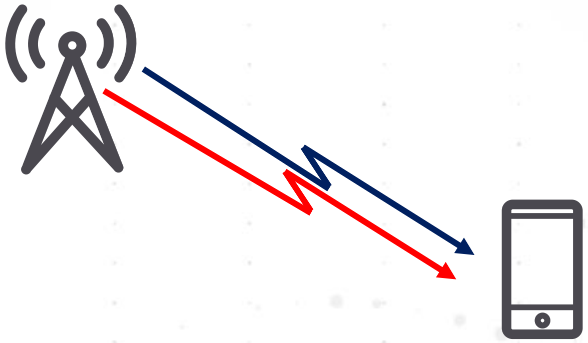


Path Loss ~ $\mathbf{f}^{2}$

Multi-antenna Transmissions



Transmit diversity for improved quality



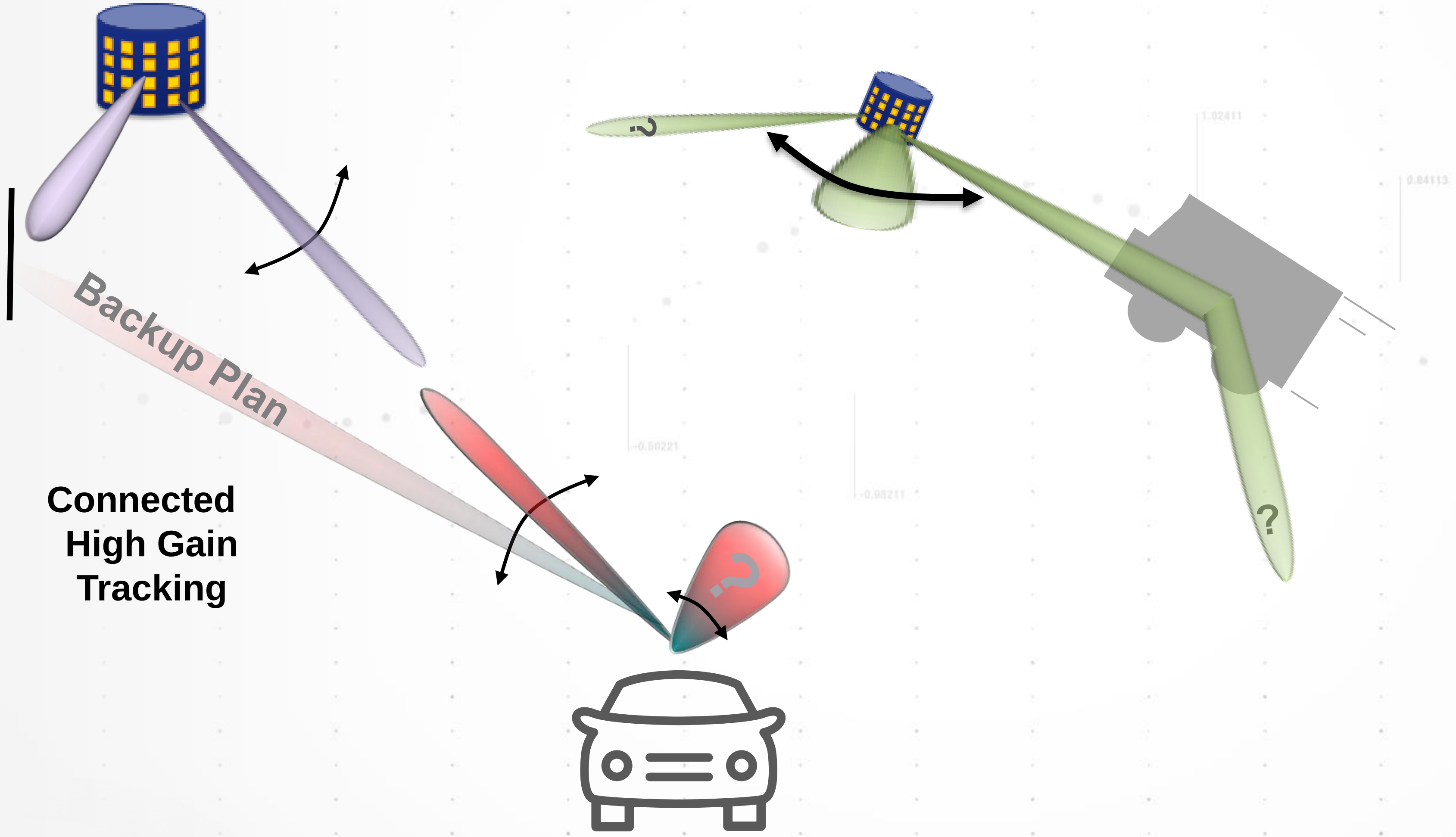
MIMO multi-layer transmission for higher data rates

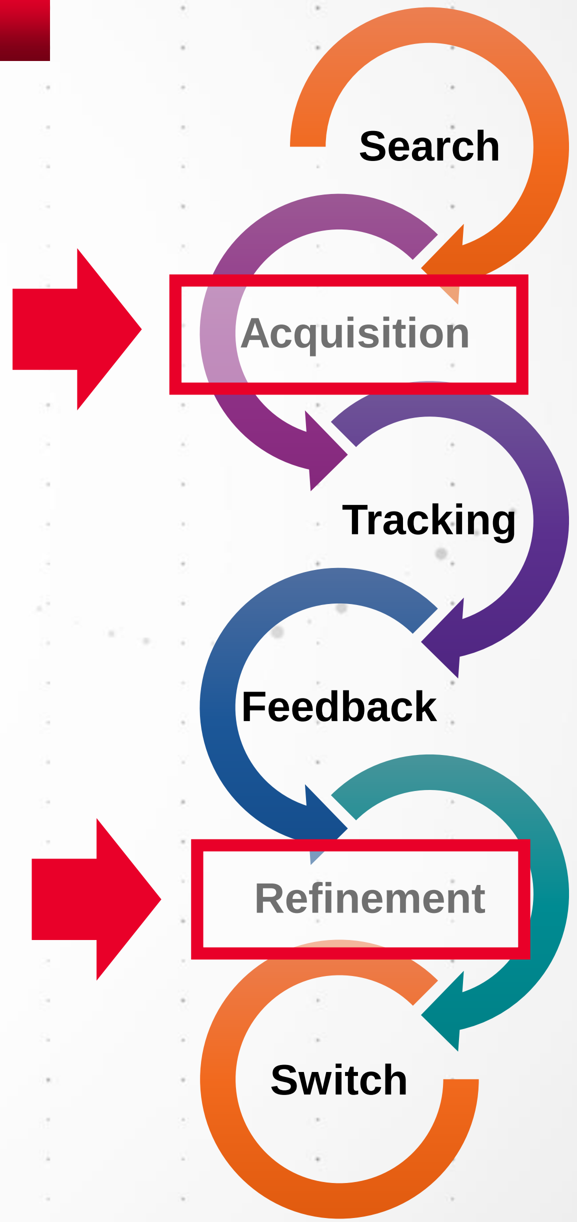
Beamforming to increase received power and SNR

Spatial multiplexing more users per cell

New Radio mmWave Spatial Domain Optimization

MOBILITY AND THE CHALLENGE OF DIRECTIONAL ANTENNAS





MIMO Variants

NO ARBITRARY DECISION – DRIVEN BY PROPERTIES OF CHANNEL

	FR1	FR2
Deployment Scenario	Macro cells High user mobility	Small cells Low user mobility
MIMO Order	Up to 8x8	Typically 2x2
Number of Simultaneous Users	Tens of users Large coverage area	A few users Small coverage area
Main Benefit	Spatial multiplexing, MU-MIMO	Beamforming for single user
Channel Characteristics	Rich multipath propagation	A few propagation paths
Spectral Efficiency	High due to the spatial multiplexing	Low spectral efficiency (few users, high path loss)

5G New Radio

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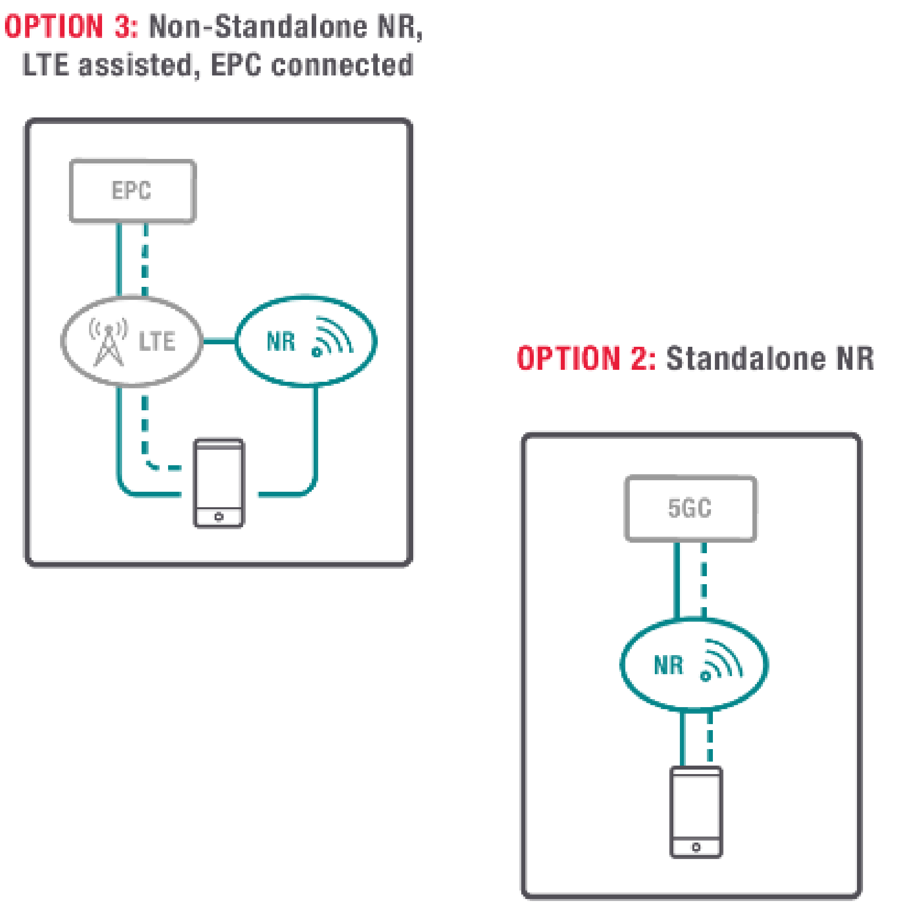
- Layer 3 (OTA) based on 4G but enhanced for control plane efficiency
- Lower layers / 5G NR greatly enhanced for the required data rates, latency, and efficiency

Non-Standalone (NSA) and Standalone (SA) Modes

JUST AN INTRO: MORE DISCUSSED LATER

- LTE coverage
  - Large existing network deployment
  - Wide coverage due to lower frequency range
- 5G network
  - System deployment will take time
  - Range is more restricted in higher frequency bands
- NSA - Dual Connectivity (DC) uses both systems for evolution, reliability and geographical coverage
  - Expectation: slow and smooth transition into 5G

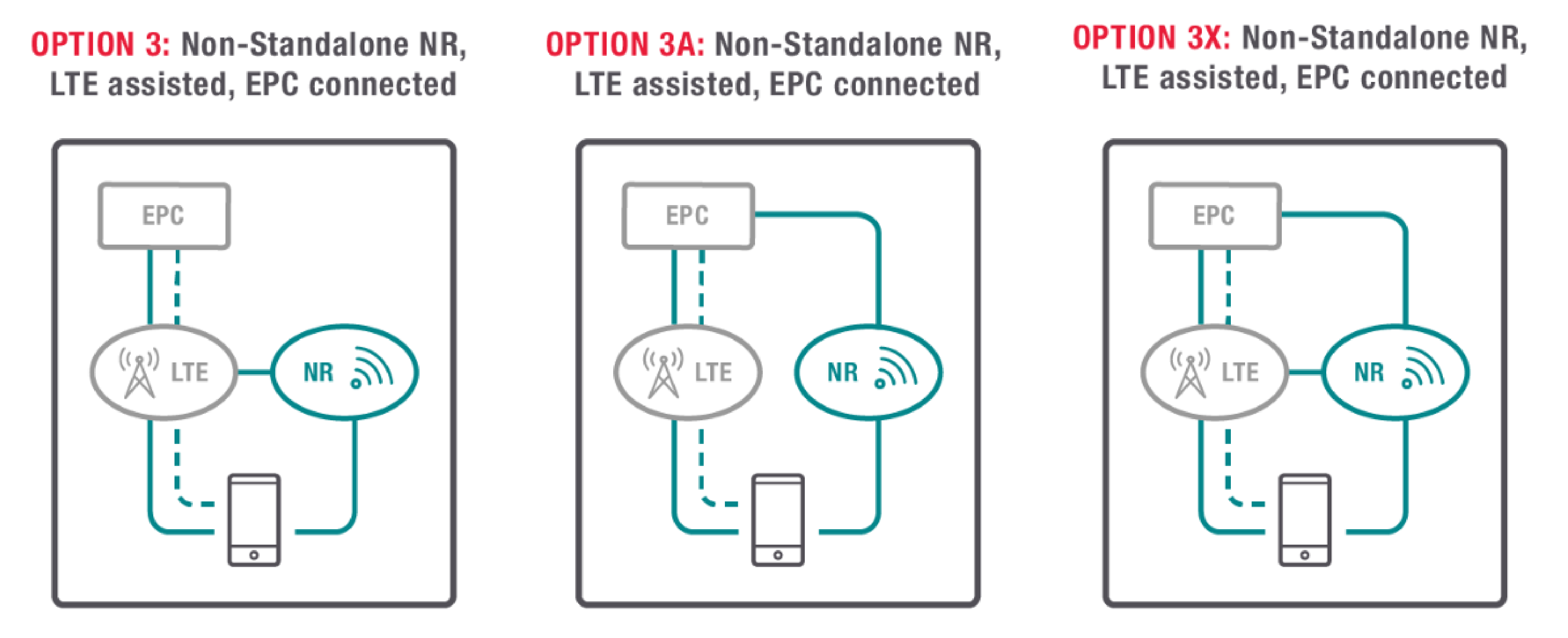


Multi-RAT Dual Connectivity with LTE Core (EPC)

OPTIONS 3/3A/3X

- Dual Connectivity with EPC: **E**-UTRA-**N**R **D**ual **C**onnectivity (**EN-DC**)
  - Master Node: eNB (LTE)
  - Secondary Node: gNB (5G NR)

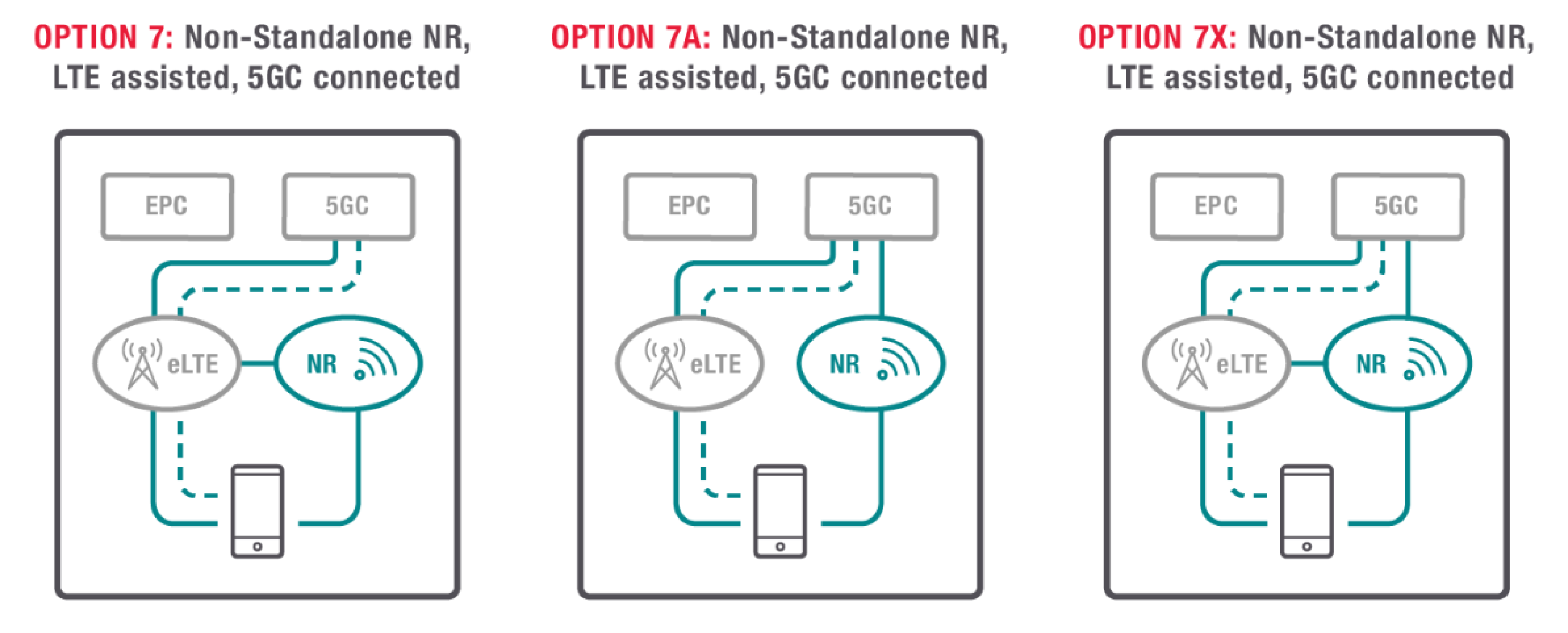
x2 interface | **No load-sharing** | **PDCP split**



Multi-RAT Dual Connectivity with 5G Core (5GC)

OPTIONS 7/7A/7X

- Dual Connectivity with NG-RAN: **NG**-RAN **E**-UTRA-**NR** **D**ual **C**onnectivity (**NGEN-DC**)
  - Master Node: ng-eNB (eLTE) – eNB evolved (eLTE)
  - Secondary Node: gNB (5G NR)

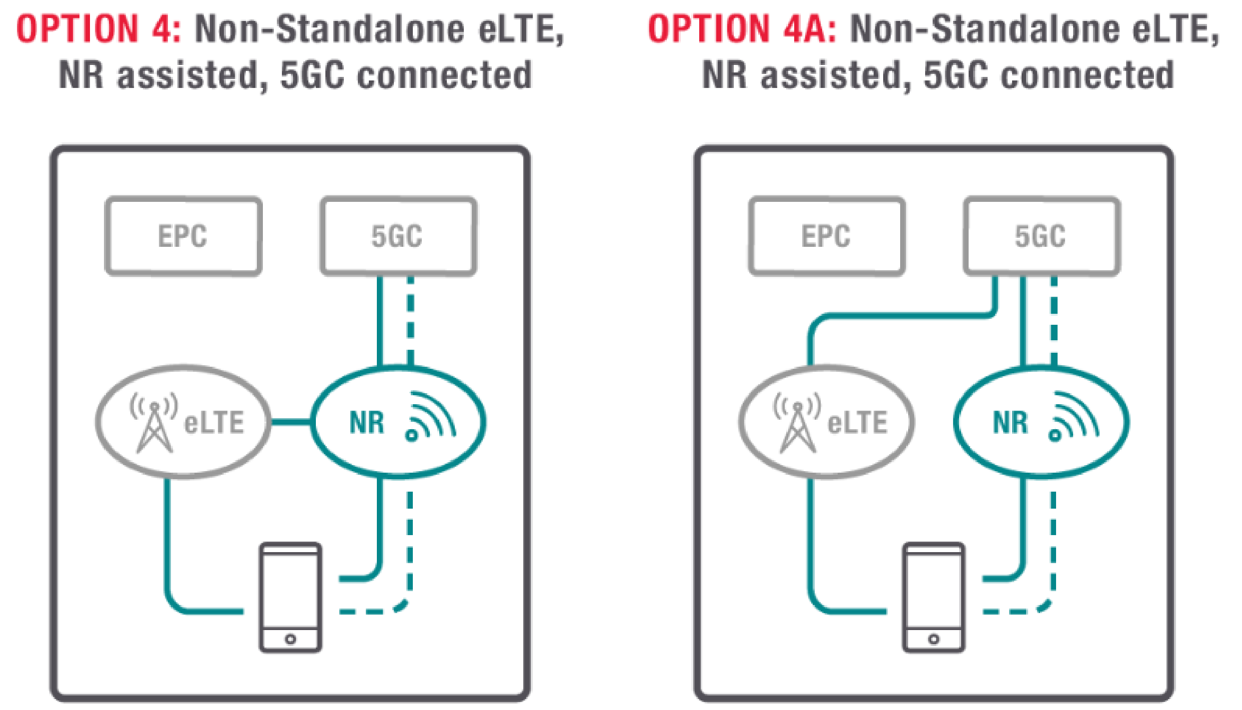


KEYSIGHT TECHNOLOGIES

Multi-RAT Dual Connectivity with 5G Core

OPTIONS 4/4A

- Dual Connectivity with NG-RAN: **N**R-**E**-UTRA **D**ual **C**onnectivity (**NE-DC**)
  - Master Node: gNB (5G NR)
  - Secondary Node: ng-eNB (eLTE)



5G New Radio

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- Lower layers / 5G NR greatly enhanced for the required data rates, latency, and efficiency

New Features Coming in Rel-16

Coming in 5G NR Rel-16 (Physical Layer)

JUST A SELECTION OF WI AND SI

- **Work Items (WI)**
  - NR-U (Unlicensed Spectrum)
  - 2-Step RACH
  - C-V2X (Vehicle to Vehicle, Infrastructure or Pedestrian) – ***Newly Added WI***
  - Enhancements for NR URLLC (Ultra Reliable Low Latency Communications) - ***Newly Added WI***

- **Study Items (SI)**
  - NOMA (Non-Orthogonal Multiple Access)

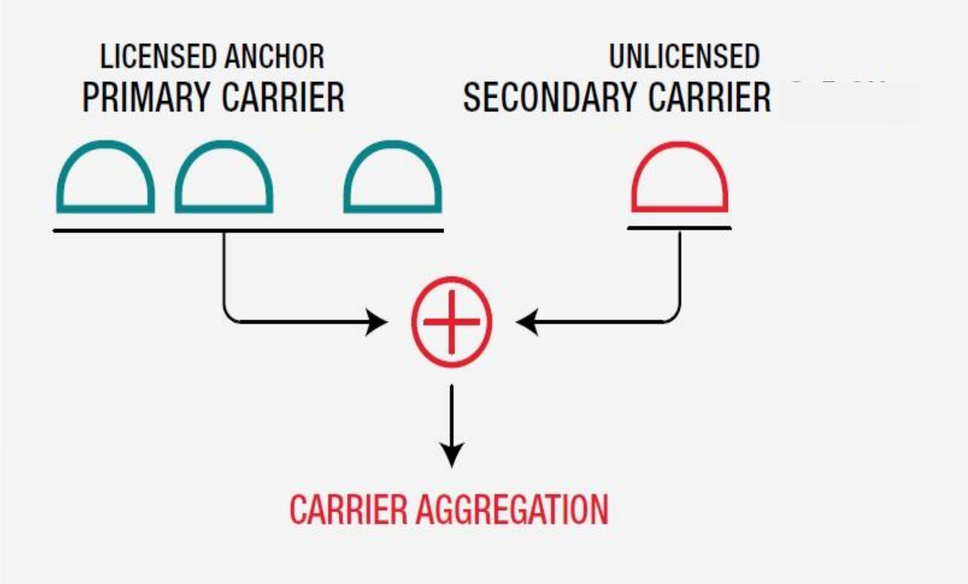
Rel-16: Unlicensed Spectrum

NR-U (WI): SCENARIOS

- Both FR1 and FR2 are considered
- Additional functionality needed (beyond existing specifications for licensed spectrum) in the following deployment scenarios:

Scenario	Description
A	Carrier aggregation between licensed band NR (PCell) and NR-U (SCell)
B	Dual connectivity between licensed band LTE (PCell) and NR-U (PSCell)
C	Stand-alone NR-U
D	A stand-alone NR cell in unlicensed band and UL in licensed band
E	Dual connectivity between licensed band NR and NR-U

Scenario A Example:



Rel-16: Unlicensed Spectrum

NR-U (WI): PHYSICAL LAYER ASPECTS

- ***LBT*** - Listen before Talk
  - Mechanism for which an equipment applies CCA before using the channel
- ***CCA*** - Clear Channel Assessment
  - Evaluation of presence/absence of other signals
- Channel access cannot be done in bandwidths ***larger than 20 MHz*** due to regulatory constraints
  - Activate/transmit the whole or part of a BWP(s) depending on the outcome of LBT procedure
- Subcarrier spacing for control and data channels supporting ***15 kHz, 30 kHz, and 60 kHz***
- ***NR-U Discovery Reference Signal (DRS)***
- Possible extension of PRACH, PUCCH and PUSCH format(s) to support NR-U operation

Rel-16: 2-Step RACH

2-STEP RACH (WI): MESSAGES A AND B

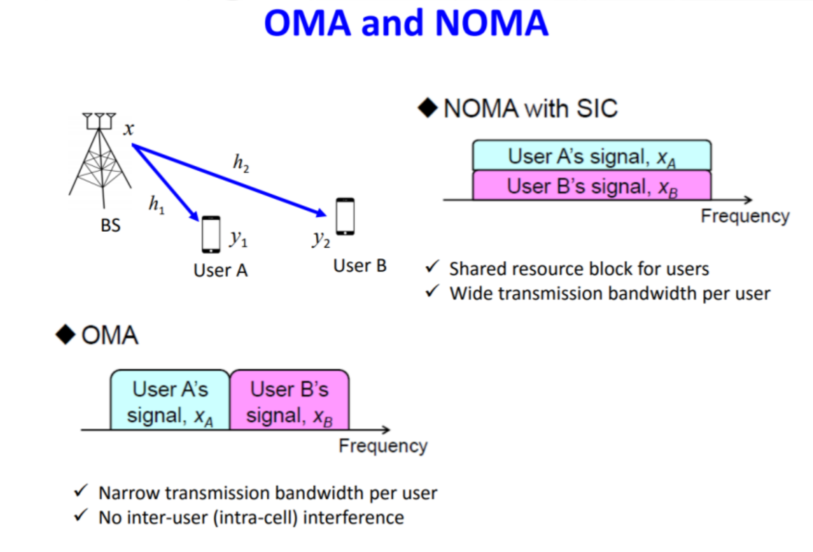
- This simplified RACH procedure reduces RACH overhead and access delay/latency
- A new msgA consists of:
  - Preamble
  - Data
- UE sends msgA via an enhanced physical random access channel (PRACH)
  - msgA includes both 4-step RACH procedure ***msg1 and msg3***
- In response to the UE request: network sends msgB using PDCCH and PDSCH
  - Message includes both 4-step RACH procedure ***msg2 and msg4***

msgA (preamble+data):

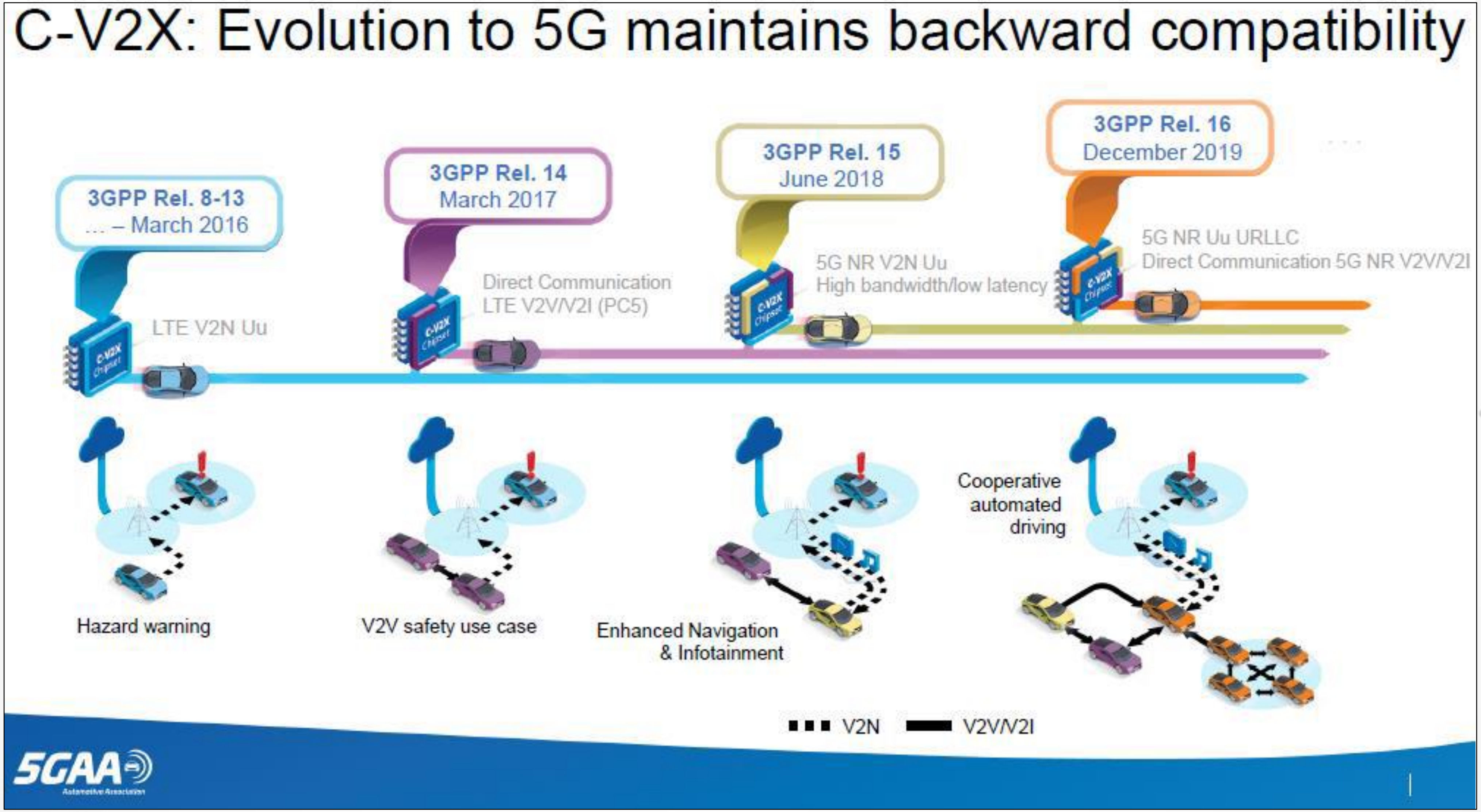
Rel-16: Non Orthogonal Multiple Access

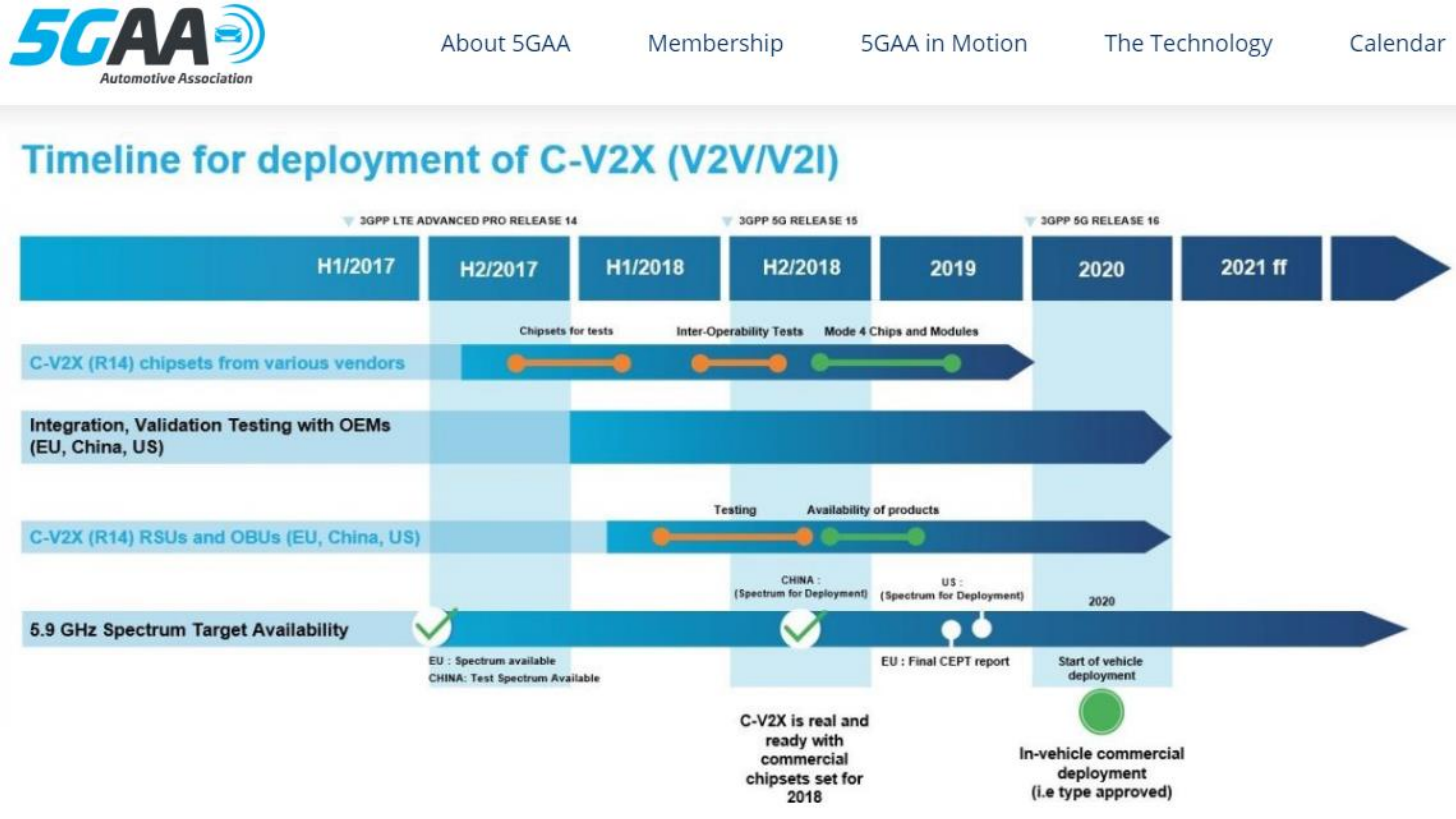
NOMA (SI):NO NOMA WI FOR REL-16 WILL BE DEFINED

- NOMA is mainly aimed to ***be used in UL***
- Attractive feature for ***mMTC*** applications: improves system load ***capability***
- The most significant gain of NOMA over MU-MIMO can be achieved in the following scenarios:
  - ***Contention-based, grant-free transmission***
  - Small data transmission from RRC_INACTIVE state
- Both grant-based and grant-free NOMA to be studied:
  - Grant-based NOMA is supported at least for eMBB scenario
  - Grant-free NOMA is supported at least for mMTC scenario
  - Grant-free NOMA can be considered for eMBB scenario



3GPP C-V2X Standard Evolution from LTE to 5G




5GAA Automotive Association
About 5GAA
Membership
5GAA in Motion
The Technology
Calendar
Timeline for deployment of C-V2X (V2V/V2I)
3GPP LTE ADVANCED PRO RELEASE 14
3GPP 5G RELEASE 15
3GPP 5G RELEASE 16
H1/2017
H2/2017
H1/2018
H2/2018
2019
2020
2021 ff
Chipsets for tests
Inter-Operability Tests
Mode 4 Chips and Modules
C-V2X (R14) chipsets from various vendors
Integration, Validation Testing with OEMs (EU, China, US)
Testing
Availability of products
C-V2X (R14) RSUs and OBUs (EU, China, US)
CHINA : (Spectrum for Deployment)
US : (Spectrum for Deployment)
2020
5.9 GHz Spectrum Target Availability
EU : Spectrum available
CHINA: Test Spectrum Available
EU : Final CEPT report
Start of vehicle deployment
C-V2X is real and ready with commercial chipsets set for 2018
In-vehicle commercial deployment (i.e type approved)

New Spectrum Band defined for C-V2X

ACCORDING TO 36.101

V2X Operating Band

E-UTRA Operating Band	V2X Operating Band	V2X UE transmit F_{UL_low}	–	F_{UL_high}	V2X UE receive F_{DL_low}	–	F_{DL_high}	Duplex Mode	Interface
47	47	5855 MHz		5925 MHz	5855 MHz		5925 MHz	TDD	PC5
3	3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	FDD	Uu
7	7	2500 MHz	–	2570 MHz	2620 MHz	–	2690 MHz	FDD	Uu
8	8	880 MHz	–	915 MHz	925 MHz	–	960 MHz	FDD	Uu
39	39	1880 MHz	–	1920 MHz	1880 MHz	–	1920 MHz	TDD	Uu
41	41	2496 MHz		2690 MHz	2496 MHz		2690 MHz	TDD	Uu

Inter-band V2X Operating Band

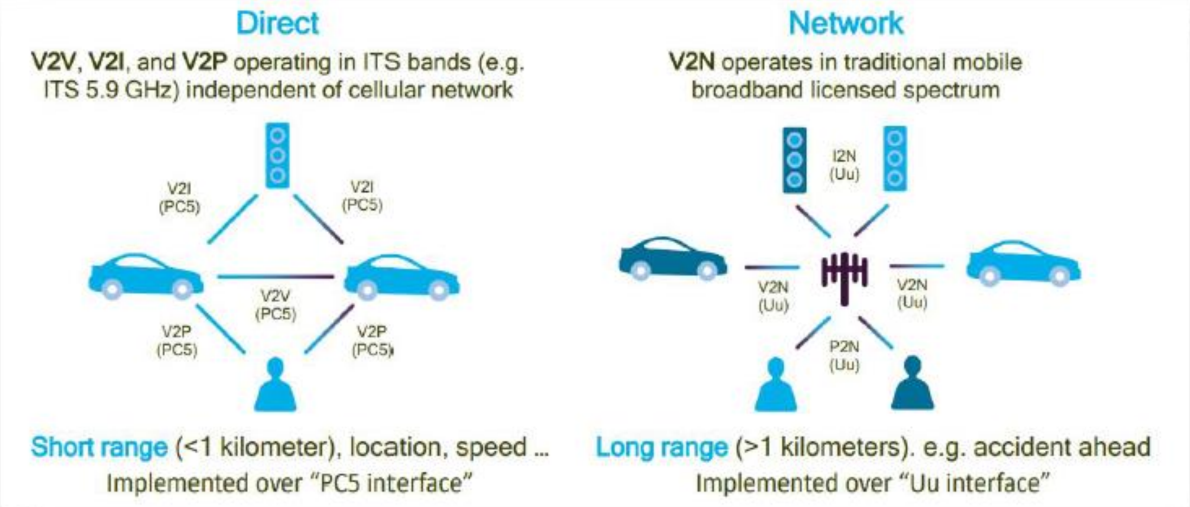
V2X con-current configuration	Operating Band	Interface	Uplink (UL) operating band BS receive UE transmit F_{UL_low}	–	F_{UL_high}	Downlink (DL) operating band BS transmit UE receive F_{DL_low}	–	F_{DL_high}	Duplex Mode
V2X_3-47	3	Uu	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	FDD
	47	PC5	5855 MHz	–	5925 MHz	5855 MHz		5925 MHz	TDD
V2X_7-47	7	Uu	2500 MHz	–	2570 MHz	2620 MHz	–	2690 MHz	FDD
	47	PC5	5855 MHz	–	5925 MHz	5855 MHz		5925 MHz	TDD
V2X_8-47	8	Uu	880 MHz	–	915 MHz	925 MHz	–	960 MHz	FDD
	47	PC5	5855 MHz	–	5925 MHz	5855 MHz		5925 MHz	TDD
V2X_39-47	39	Uu	1880 MHz	–	1920 MHz	1880 MHz	–	1920 MHz	TDD
	47	PC5	5855 MHz	–	5925 MHz	5855 MHz		5925 MHz	TDD
V2X_41-47	41	Uu	2496 MHz	–	2690 MHz	2496 MHz		2690 MHz	TDD
	47	PC5	5855 MHz	–	5925 MHz	5855 MHz		5925 MHz	TDD

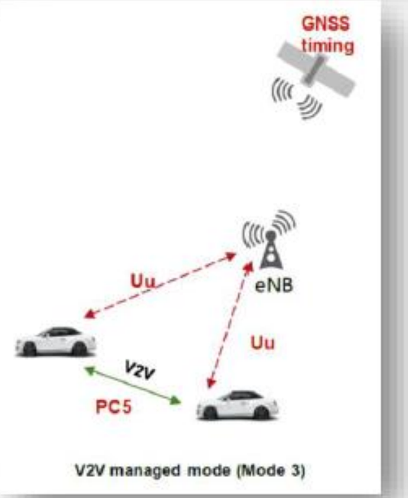
V2X intra-band MCC operation

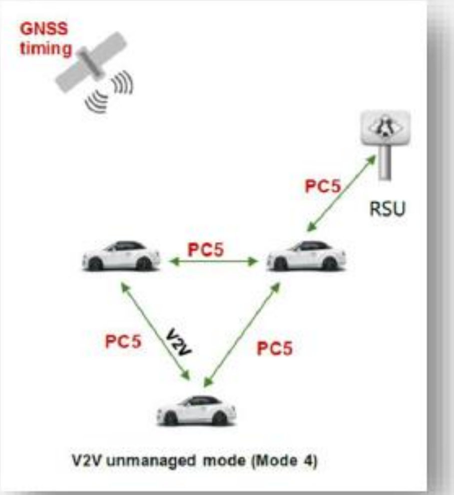
V2X MCC Band	V2X operating Band	Interface
V2X_47	47	PC5

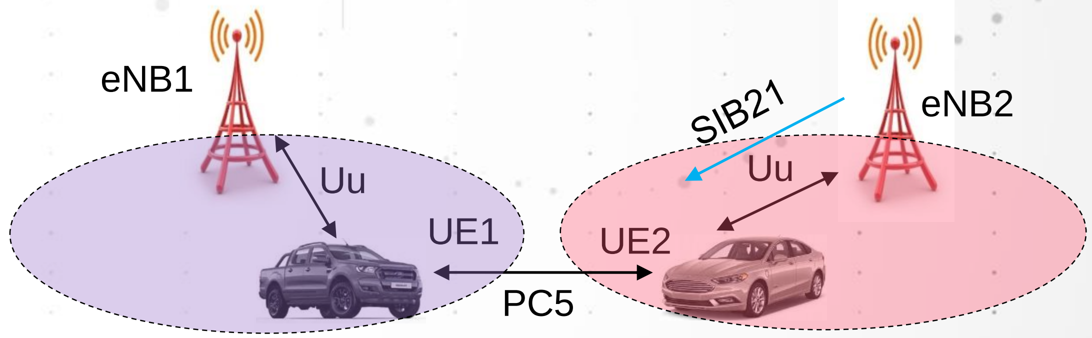
C-V2X

Two Complementary Communication Modes (Direct and Network) and Scenarios (Served or not by the Network)







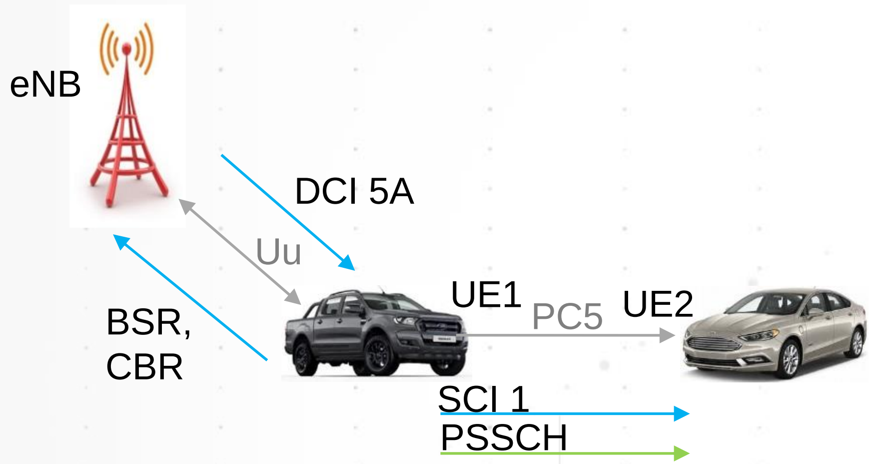


C-V2X

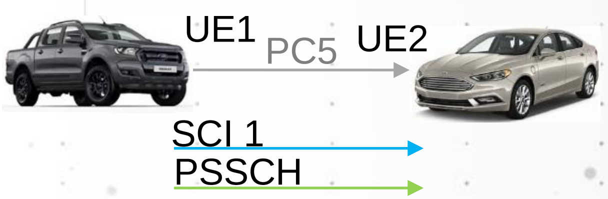
Two modes of direct communication in PC5: Transmission Mode 3 and 4

Signaling

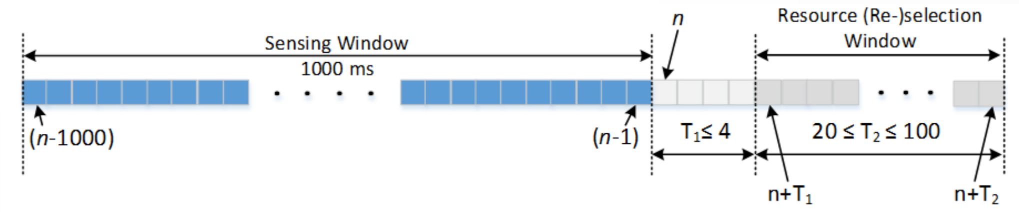
Data

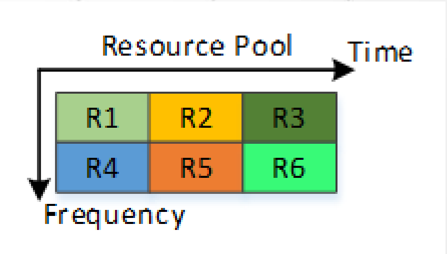


Transmission Mode 3



Transmission Mode 4

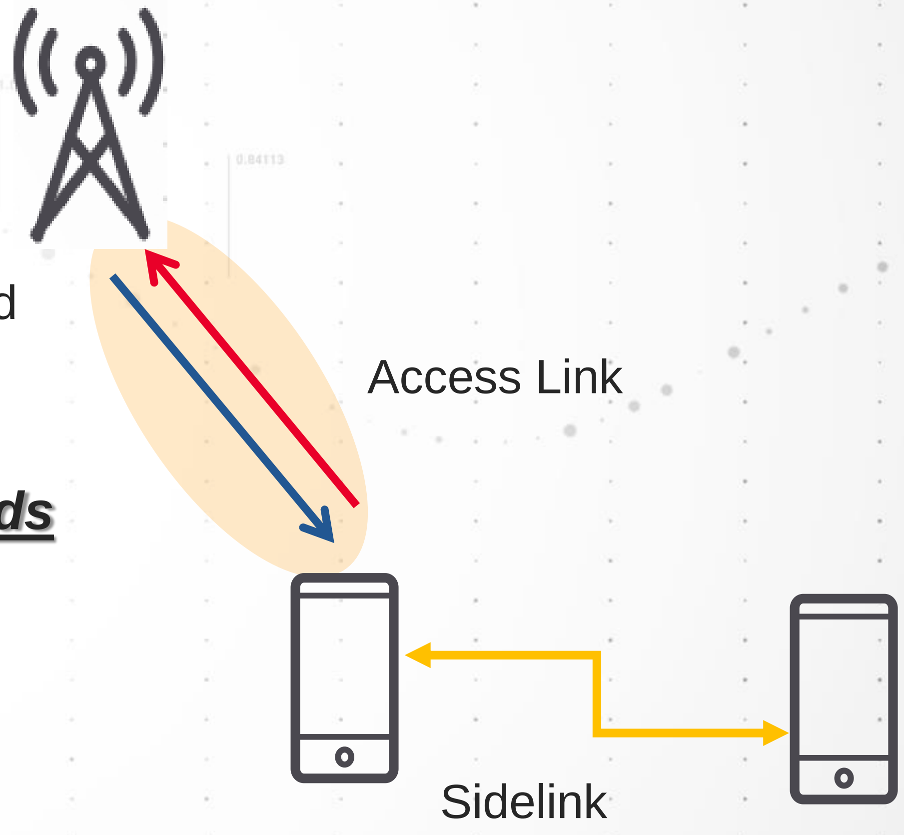




Rel-16: Cellular Vehicle to Everything (C-V2X)

V2X (SI→WI): SIDELINK

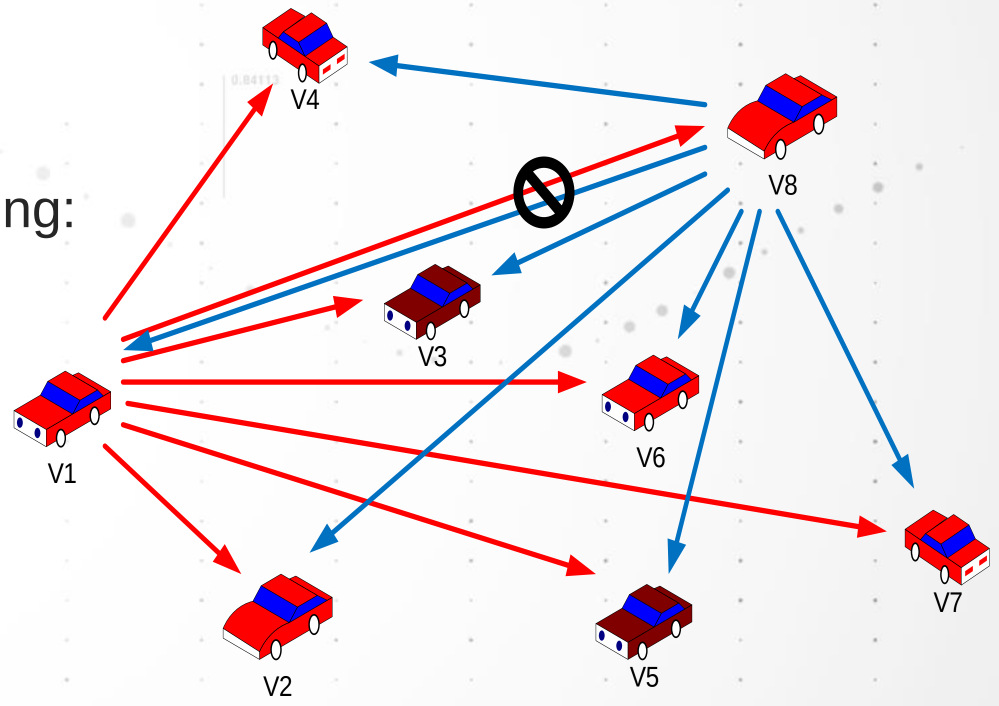
- The ***access link*** (i.e. DL/UL) is used for communication between gNB and UEs
- The ***sidelink*** is used for communication between UEs
  - This is the link used for V2X in LTE and NR
- NR V2X will support: ***unicast***, ***groupcast*** and ***broadcast***
  - For unicast: HARQ feedback and HARQ combining are supported
  - For groupcast: HARQ feedback and HARQ combining are supported
- NR V2X is expected to work ***in licensed & unlicensed bands***
- NR-V2X sidelink should be able to operate:
  - ***Out of coverage***
  - ***Partial coverage***
  - ***In-coverage***



Rel-16: C-V2X

V2X (SI→WI): SIDELINK PHYSICAL CHANNELS

- The following channels are at least defined for NR V2X:
  - ***PSSCH***
  - ***PSCCH*** (at least carries information necessary to decode PSSCH)
  - ***PSFCH*** (contains sidelink feedback control information transport channel (SFCI))
- NR V2X sidelink synchronization includes at least the following:
  - ***S-SSB***: NR SSB structure as the starting point
    - Sidelink PSS and SSS (S-PSS and S-SSS)
    - PSBCH
- ***Periodic transmission of S-SSB*** is supported
  - Sidelink SSB should be designed to be distinguishable from NR SSB
    - Different frequency position and different relative time positions
- ***Half-Duplex restriction***:
  - Once UE is in the transmission mode, it is not able to receive
  - This could significantly reduce the packet reception ratio (PRR)



Rel-16: Enhancements for NR URLLC

ENHANCEMENTS FOR NR URLLC (SI→WI): JUSTIFICATION

- In Rel-15, the basic support for URLLC was introduced with:
  - TTI structures for low latency
  - Methods for improved reliability
- Rel-15 enabled use case improvements
  - Such as AR/VR (i.e. entertainment industry)

- FR1 and FR2, TDD and FDD are eligible for enhancements to NR URLLC

- The study item in Rel-16 is focusing on the following items:
  - Higher reliability and higher availability
  - Time synchronization
  - Short latency ~ 0.5 to 1 ms

Rel-16: Rel-16: Enhancements for NR URLLC

ENHANCEMENTS FOR NR URLLC (SI→WI): NEW USE CASES

Use Case	Reliability	Latency	# of UEs (per cell)	Traffic Model	Description
Transport Industry	99.999%	5 ms	30	Periodic	Remote driving
Power Distribution	99.9999%	5 ms	8	80 bytes	Power distribution Grid fault Outage management
	99.999%	15 ms	8	250 bytes Periodic	Differential protection
Factory automation	99.9999%	2 ms	40	20 bytes Periodic	Motion control
Rel-15 use case (e.g. AR/VR)	99.999%	1 ms	20	256 bytes	AR/VR

5G Standards and Test Requirements

3GPP Organization

Today's Focus

RAN 5G NR Summary Reference Documents		
TSG RAN Radio Access Network	Study Items for New Radio Access Technology	Resulting Specifications
RAN WG1 Radio Layer 1 spec	**TR 38.802** Physical Layer Aspects	**TS 38.201 –TS 38.215**
RAN WG2 Radio Layer 2 spec Radio Layer 3 RR spec	**TR 38.804** Radio Interface Protocol Aspects	**TS 38.300–TS 38.331**
RAN WG3 Iub spec, Iur spec, Iu spec UTRAN O&M requirements	**TR 38.801** Radio Access Architecture and Interface	**TS 38.401 – TS 38.474**
RAN WG4 Radio Performance Protocol Aspects	**TR 38.803** RF and Coexistence aspects	**TS 38.101 – TS 38.173 (+38.307)**
RAN WG5 Mobile Terminal Conformance Testing	**TR 38.80x**	**TS 38.508 – TS 38.533**

Overview of 3GPP 5G New Radio Standards

CONFORMANCE TESTS

5G NR RAN Working Groups

	Study Items for New Radio Access Technology	Specifications
RAN1 Radio Layer 1	TR 38.802 Physical Layer Aspects	TS 38.201 – TS 38.215
RAN2 Radio Layer 2 and Radio Layer 3	TR 38.804 Radio Interface Protocol Aspects	TS 38.300 - TS 38.331
RAN3 Radio Network	TR 38.801 Radio Access Architecture and Interface	TS 38.401 – TS 38.474
RAN4 Radio Performance and Protocol	TR 38.803 RF and co-existence aspects	TS 38.101 – TS 38.173 (+38.307)
RAN5 Mobile Terminal Conformance Tests	TR 38.80x	TS 38.508 – TS 38.533

5G NR Conformance Tests

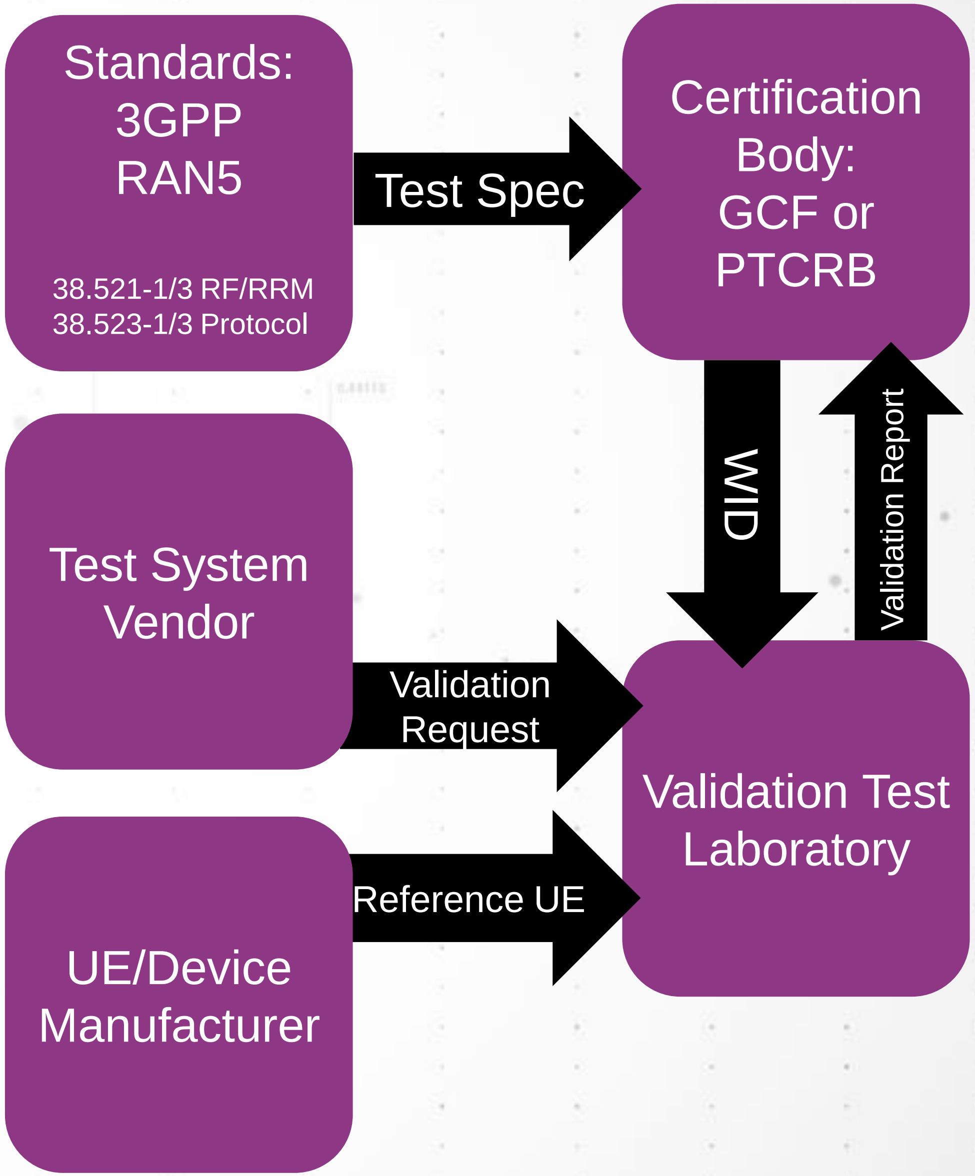
Base Stations TS 38.141-1 TS 38.141-2	**Part 1**: Conducted testing in FR1 **Part 2**: **Radiated** testing for specific base station configurations in FR1 & FR2
Devices TS 38.521-1/2/3/4 TS 38.523-1/2/3 TS 38.533	**5G NR UE Radio Transmission & Reception:** 1. Range 1 Standalone – FR1 Conducted Tests 2. Range 2 Standalone – **FR2 Radiated Tests** 3. Range 1 & 2 Interworking operation with other ratios (NSA) – FR1 Conducted & **FR2 Radiated** 4. Performance requirements (SA and NSA) – FR1 Conducted & **FR2 Radiated** **5GS UE Protocol Conformance** 1. Protocol 2. Applicability of protocol test cases 3. Protocol test suites **5G NR Radio Resource Management (RRM)** (SA and NSA) - FR1 Conducted & **FR2 Radiated**

Other UE Conformance docs: TS 38.508-1/2, TS 38.509, TS 38.522

Device Conformance and Operator Acceptance Tests

Process to Ensure 5G UE Conformance

- Standards bodies, certification bodies, test equipment vendors and 5G NR device makers together ensure conformance to 5G specifications
- GCF and PTCRB certification organizations are ready to validate 5G conformance test cases and to start with the certification of the 5G devices



Carrier Acceptance Tests

- Defined by operators
- Validated by operators

Typical steps for devices

Interop Testing → Field Trials → Protocol & RF → NS-IOT

KEYSIGHT TECHNOLOGIES

UE Conformance Tests Summary – 1 of 2

RADIO TRANSMISSION AND RECEPTION

FR1 Conducted Tests
FR2 Radiated Test

Transmitter Characteristics	Receiver Characteristics	Interworking Operation	Performance
• **Transmitter Power** (UE Max Output Power, Power Reduction, CA, SUL, UL-MIMO ...) • **Output Power Dynamics** (Min Power, Tx OFF Power, On/OFF Time Mask, Power Control) • **Signal Quality** (Freq Error / EVM / Carrier Leakage, In-Band Emissions, CA...) • **Spectrum Emissions** (Occupied BW / SEM/ ALCR / Spurious /... SUL, UL-MIMO) • **Tx Intermodulation (FR1)**	• **Reference Sensitivity Level** (Intra-band Contiguous, Non-Contiguous, Inter-Band, DC, SUL, UL-MIMO) • **Maximum Input level** (CA, UL-MIMO, Adjacent Channel Selectivity) • **Blocking Characteristics** (In-Band, Out-of-Band • **Spurious Response** • **Intermodulation Characteristics** • **Spurious Emissions** • **Rx Intermodulation (FR1)**	Most of the same Tx and Rx characteristics tests under different carrier aggregation (CA) configuration between 5G NR frequency range 1 and 2 and non-standalone operations with E-UTRA (EN-DC)	**Still being defined**
CURRENT STATUS March 2019			
• **Partial Tx test done single carrier, CA later** • **MOP, EIRP, TRP first completed FR2 test**	• **Very little Rx test done, single carrier, CA later** • **No FR2 yet**	• **Partial done for NSA opt 3 DC (some CA, but not complete yet)**	**1 test case close to 100% completed: 2Rx TDD perform – 2x2 MIMO**

UE Conformance Tests Summary

RRM AND PROTOCOL

FR1 Conducted Tests
FR2 Radiated Test

Protocol	RRM Test Coverage
• Protocol Idle Mode • Layer 2 • Random access procedures, DL data transfers, UL data transfers, transport size, • Protocol RRC procedures • Mobility management • Session management	**Ensures efficient use of the radio resources in standalone (FR1 & FR2) and non-standalone (E-UTRA & 5G NR interworking)** • EN-DC option 3 (NR PSCell in FR1) • EN-DC option 3 (NR PSCell in FR2) • SA option 2 (NR Pcell in FR1) • SA option 2 (NR Pcell in FR2)
CURRENT STATUS March 2019	
Mostly done SA opt 2 and NSA opt 3	Still Being Defined 2 tests are 100% completed

Considerations for Radiated Tests

Paradigm Shift in Test

RADIATED TEST MOVES TO THE MAINSTREAM

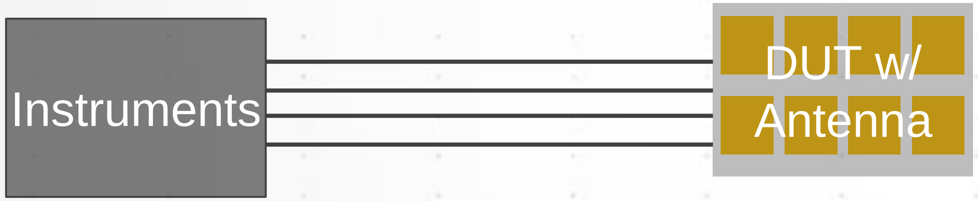
Discrete components, cabled, easy to test

ADC/DAC MODEM | RF | Antenna

mmWave DUTs now all integrated, no probing connectors, harder to test

ADC/DAC MODEM | RF | Antenna

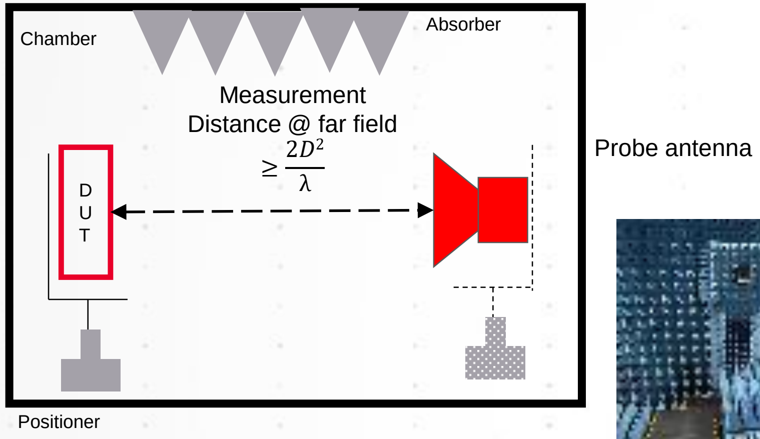
Connected Test Setup: Preferred for nearly all LTE and NR FR1 Tests



Radiated tests mandatory for ALL FR2

Radiated Test Methods for FR2 Conformance

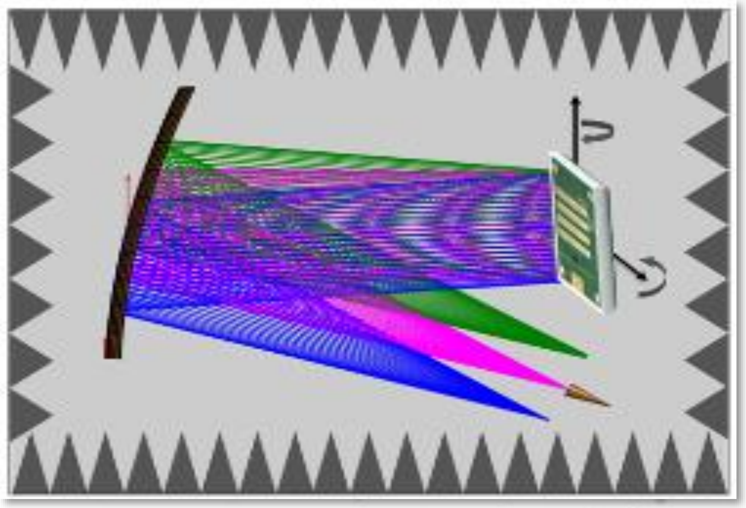
Direct Far Field



✓Antenna beam pattern characterization
✓Beamforming/beamsteering validation
✓RF parametric tests (if S/N high enough)

× Subject to higher path loss
× Large chambers at mmWave frequencies

Indirect Far Field

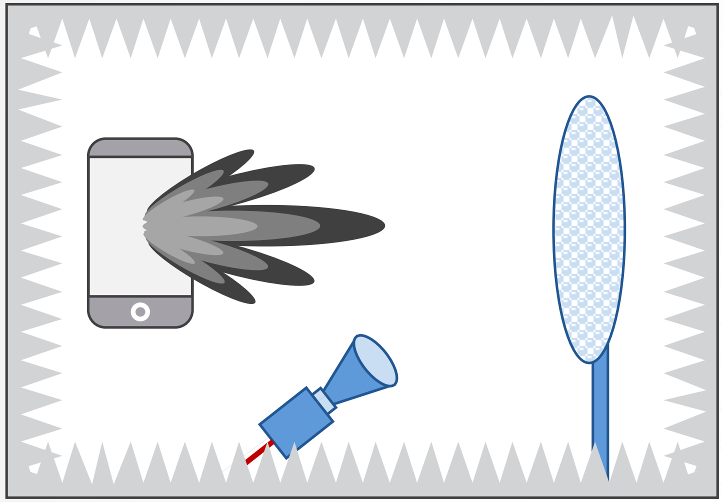


✓Antenna Beam pattern characterization
✓Beamforming/steering validation
✓RF parametric tests
✓Small footprint, lowest path loss

× Rx spatial field generation not defined

Different Chambers for Different Tests

Compact Antenna Test Range



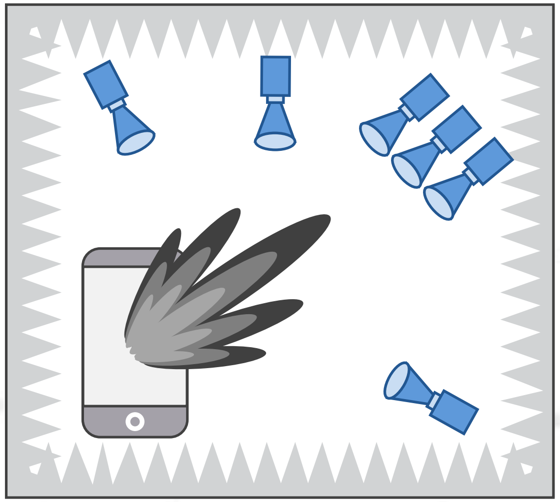
Indirect Far-Field

RF Conformance

Frequency: FR2 24 – 52 GHz (in-band), 6 - 110 GHz (out-of-band)

Target Devices: Antennas/ modules, phone, tablets, small gNB

Spatial Multiprobe Anechoic Chamber



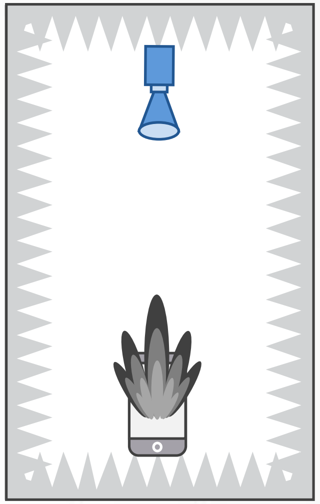
Direct Far-Field

RRM for Multi-AoA
NR-MIMO

Frequency: FR2 24 - 44 GHz

Target Devices: Modules, phones, phablets, mobile test platforms

Single AoA DFF



Direct Far-Field

Protocol Test With Single AoA

Frequency: FR2 24 - 44 GHz

Target Devices: Modules, phones, phablets, mobile test platforms

Summary

Key Takeaways

UNDERSTANDING THE ROAD AHEAD

- Standards will continue to evolve through Rel-16 and beyond: your test solutions need to be flexible and scalable
- Higher frequencies, wider channel bandwidths, and dual connectivity increase the number of test cases and test complexity
- mmWave and MIMO introduce new OTA test requirements for 5G NR devices and base stations
- New initial access and control procedures will require more testing
- Higher frequencies, wider bandwidths, dual connectivity, increased # test cases, increased test times, and OTA all increase test complexity
- Conformance test methods are not complete – many challenges ahead
- Standards continue to evolve. Release-16 is due mid 2020 and early work on Release-17 has begun.

Summary

UNDERSTANDING THE ROAD AHEAD

- Higher frequencies, wider bandwidths, dual connectivity, increased # test cases, increased test times, and OTA all increase test complexity

- Conformance test methods are not complete –many challenges ahead

- Standards continue to evolve. Release-16 is due mid 2020 and early work on Release-17 has begun.

Keysight 5G Solutions for All Parts of the Ecosystem

5G Network Test

- Drive Test and Analytics
- UE Emulation and Load Test
- Network Simulation and Test

5G Signaling Validation Test

- 5G NR Protocol Validation
- Radio Signaling Test
- 5G NR Conformance Test

Physical Layer Design and Test Solutions

- System-Level Simulation
- Component Characterization
- Digital Conformance Test
- Parametric Signal Test
- RF and mmWave Radiated Test
- Manufacturing Test Automation