KEYSIGHT WORLD 2019

Understanding 5G New Radio Release 15/16 Standards

Keysight Technologies

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Understanding 5G NR Standards

AGENDA – 2 HOUR SESSION

- Technology Overview & Timelines
- Carrier Aggregation & Bandwidth Adaptation
- Numerology & Frame Structure
- Waveforms & Modulations
- Protocol Structure, Layers, Signals & Channels
- Beams, Beamforming & Beam Management
- Initial Access Procedure, Example Call Flows
- Network Architecture, Deployment Options
- New Features Coming in Rel-16

5G

Technology Overview & Timeline

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

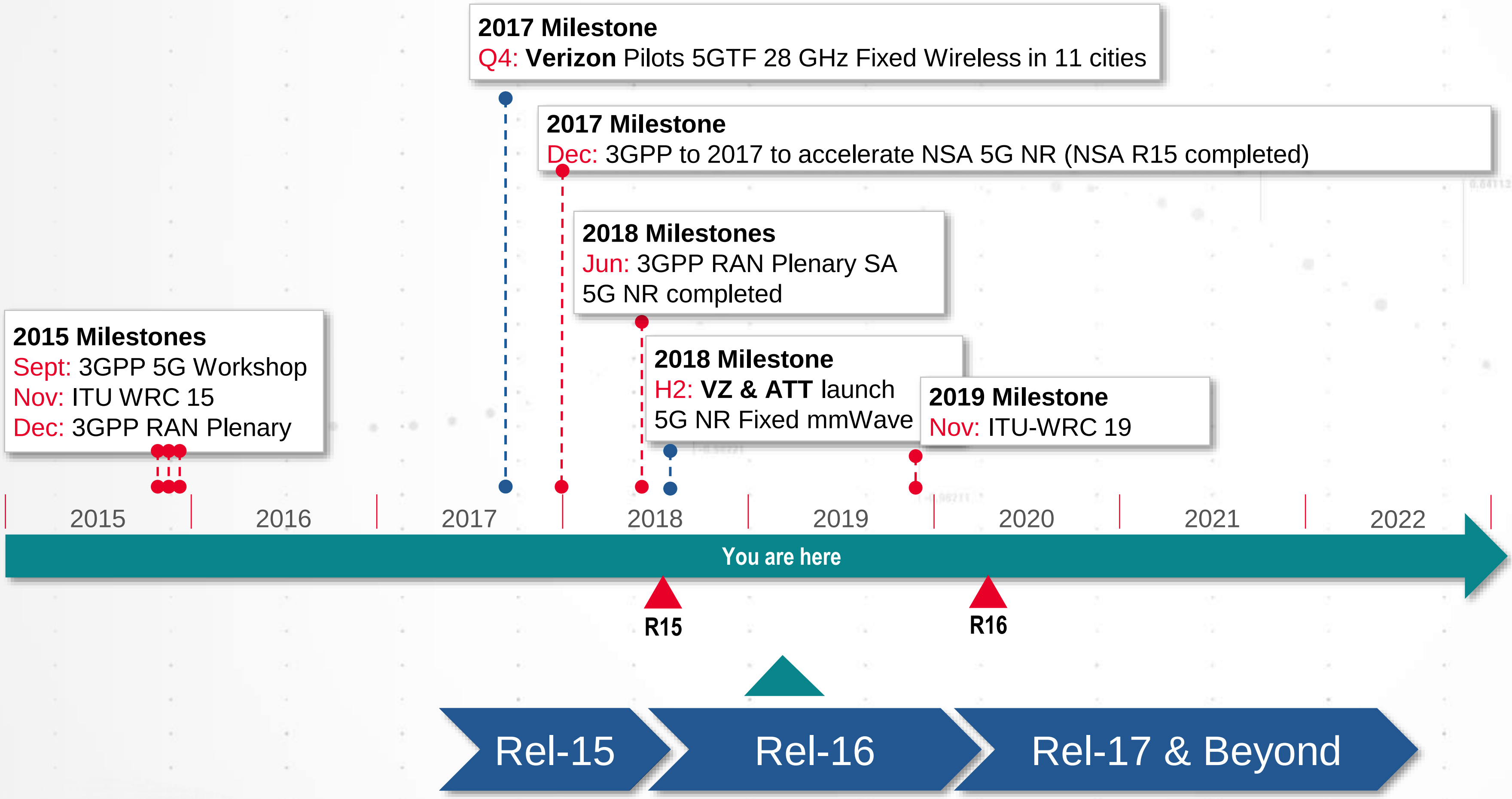
- Focus on **mMTC** and **URLLC**
- Novel layers and architecture to allow full 5G potential (vehicular and multicast services)
- “mmWave” 28, 37, 39 GHz channels and unlicensed spectrum

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

2015 2016 2017 2018 2020

5G Timing: Drivers

KEY MILESTONES AND CARDINAL DATES



Commercialization Announcements

- **Verizon:** Fixed mmWave in 2018
- **AT&T:** Fixed mmWave in 2018
- **T-Mobile:** Sub-6 GHz 5G in 2019
- **Sprint:** Sub-6 GHz 5G in 2019
- **KT:** 5G in 2019
- **DOCOMO:** 5G in 2020
- **China Mobile:** 5G in 2020

- Timelines more aggressive than in previous generations
- Scope and difficulty higher than in previous generations

As of March 2019 with *no scope change*:

- 3-month delay in Rel-16 and Late Drop of Rel-15.

5G New Radio – 1

AT A GLANCE – KEY DISTINCTIVE FEATURES

- 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

NEW

3GPP TS 38.521-2 Table 5.3.5-1

FR2: NR band / SCS / UE Channel bandwidth					
NR Band	SCS kHz	50 MHz	100 MHz	200 MHz	400 MHz
n257	60	Yes	Yes	Yes	N/A
	120	Yes	Yes	Yes	Yes
n258	60	Yes	Yes	Yes	N/A
	120	Yes	Yes	Yes	Yes
n260	60	Yes	Yes	Yes	N/A
	120	Yes	Yes	Yes	Yes

5G New Radio -2

AT A GLANCE – KEY DISTINCTIVE FEATURES

- 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

Data

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

Data

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

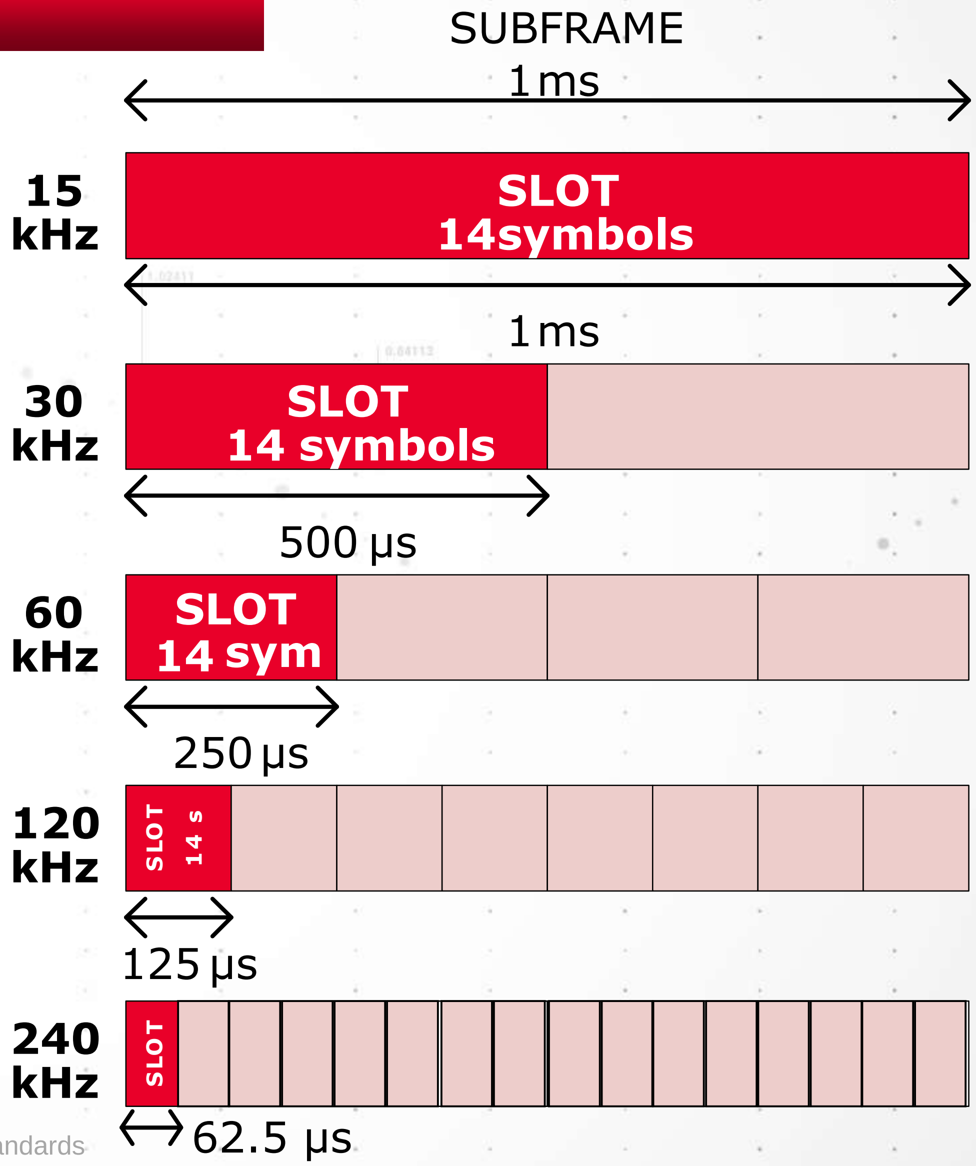
FRAME STRUCTURE & NUMEROLOGY

Slot structure is flexible to provide for better spectrum utilization

- <u>**SCS**</u>: 15 kHz*2n
- <u>**Frame**</u>**: 10 ms**
- Subframe: Reference period of 1 ms
- <u>**Slot**</u> **(slot based scheduling)**
  - **14 OFDM symbols**, or 12 with extended CP
  - One possible scheduling unit
  - Slot length scales with the subcarrier spacing

NEW

- <u>**Mini-Slot**</u> **(non-slot based scheduling)**
  - 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)

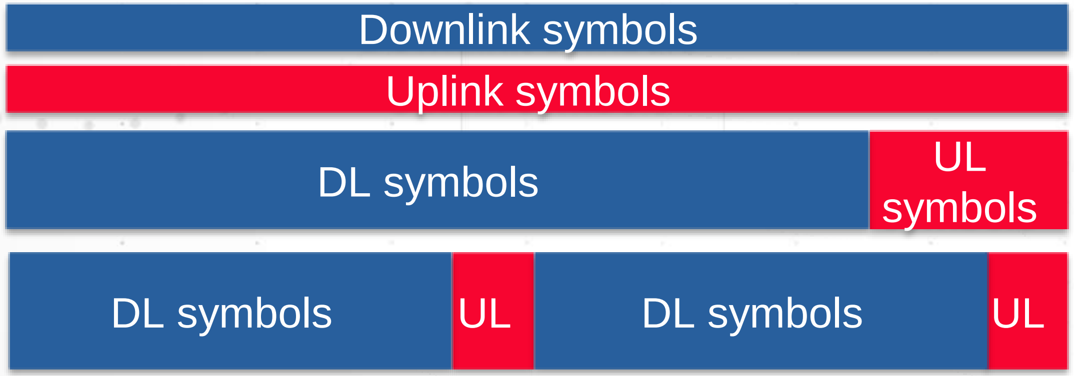
- Downlink only (Slot Format 0, used in FDD)
- Uplink only (Slot Format 1, Used in FDD)
- Flexible: Downlink and Uplink (static, semi-static (RRC) or dynamically scheduled (DCI))

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

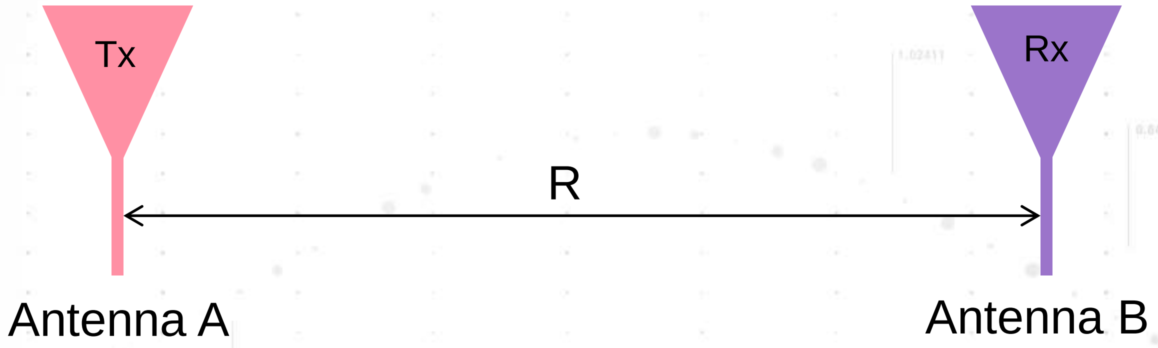
Downlink-centric SF **Uplink-centric SF**

- 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 - 3

AT A GLANCE – KEY DISTINCTIVE FEATURES

- 3D **Beamforming** antennas - MU-MIMO steerable on per UE basis, massive MIMO



The relation between the transmitted power in A and the received power in B is given by the ***Friis Transmission Formula***:

$$P_{rx} = \frac{P_{tx}}{4\pi R^2}\frac{\lambda^2}{4\pi}G_{rx}G_{tx}$$

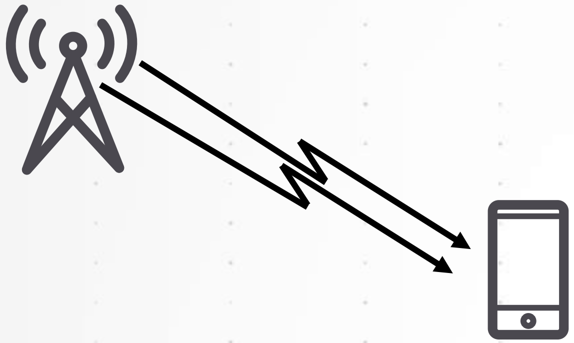
$$\lambda_0 = \frac{c_0}{f} \quad \text{(free space)}$$

Can be used to increase P_{rx} (limited)

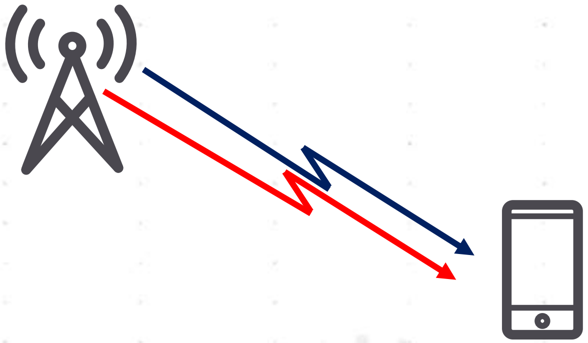
Propagation losses

Can be used to increase P_{rx}

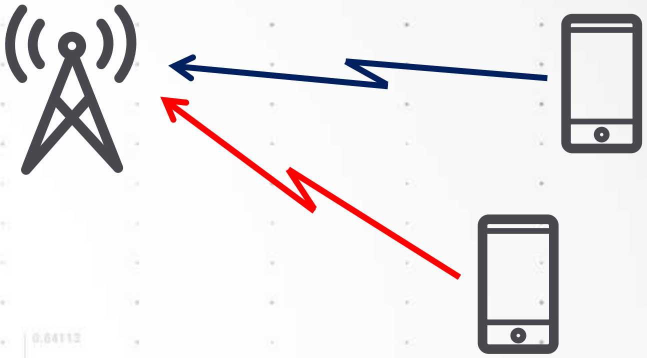
Multi-antenna Transmissions



Transmit diversity for improved quality



MIMO multi-layer transmission for higher data rates



Multi-user MIMO (UL) more users per cell

Beamforming to increase received power and SNR

Spatial multiplexing more users per cell

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 – 4

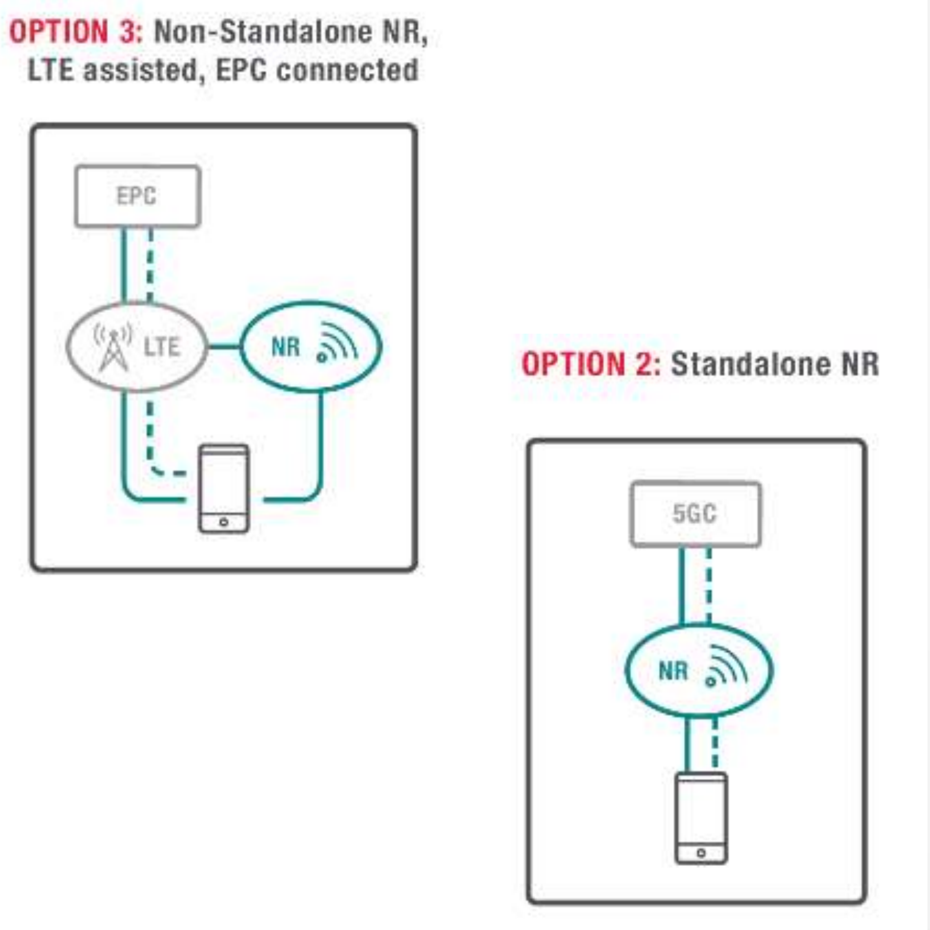
AT A GLANCE – KEY DISTINCTIVE FEATURES

- 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

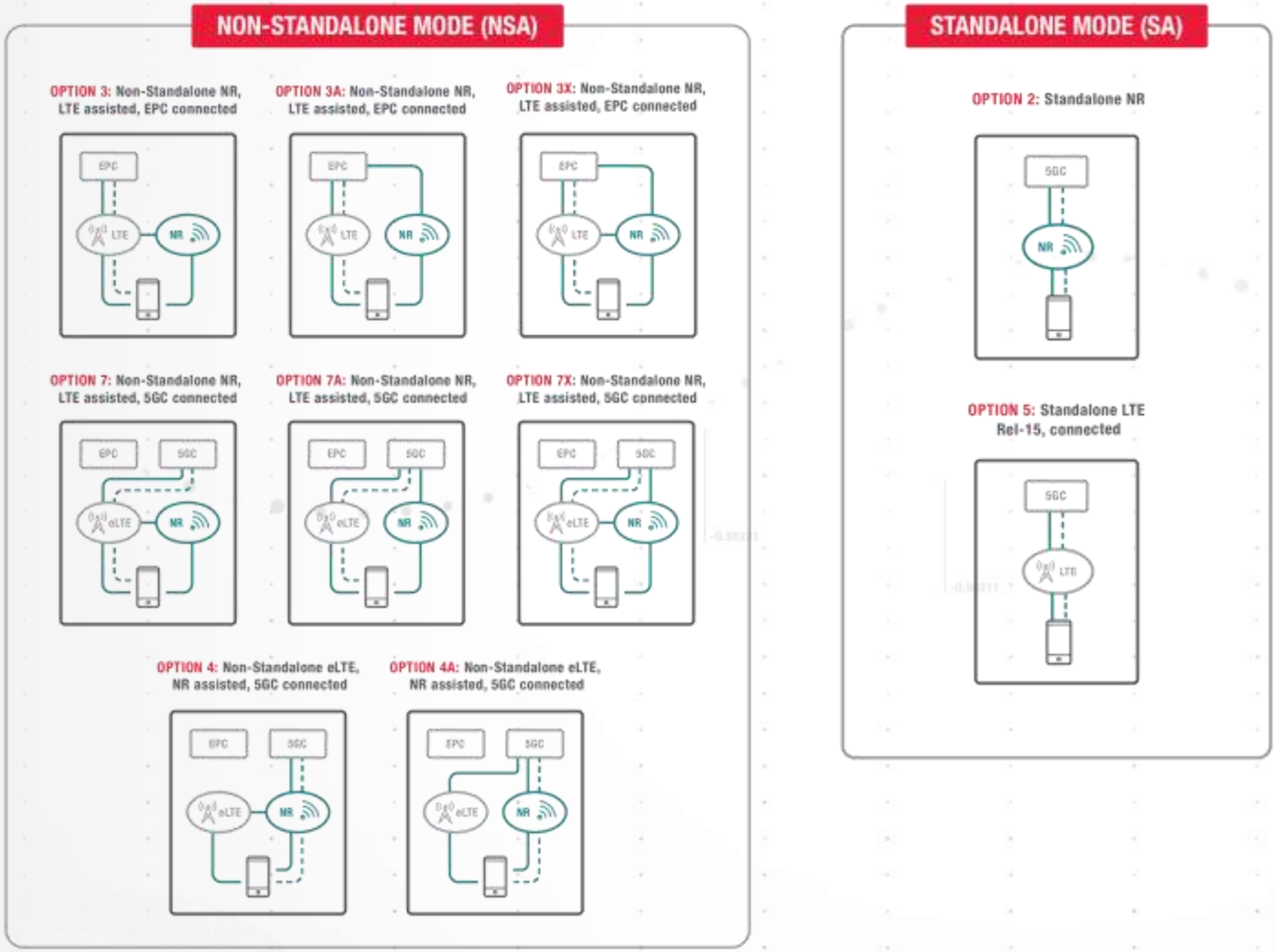


NSA: Dual Connectivity Across LTE and NR

RAT	NSA	SA
	Connection to both LTE and 5G mandatory	Can work with 5G only (LTE not necessary)
Control (Location Registration)	5G focused on U-Plane alone, LTE used for control including call origination/termination, location registration, etc.	5G used for both U-Plane and C-Plane
5G radio control parameters	5G radio control parameters exchanged through LTE, functions added to eNB	5G radio control parameters exchanged through 5G
Paging Channels	UE monitors paging channels on LTE	UE monitors paging channels on 5G

5G NR Deployment Options

START WITH NSA



Rel-15 Early Drop (December 2017)

- NR NSA – eNB as master node
- 4G Core Network (EPC)
- Enhanced LTE (eLTE)

Rel-15 (June 2018)

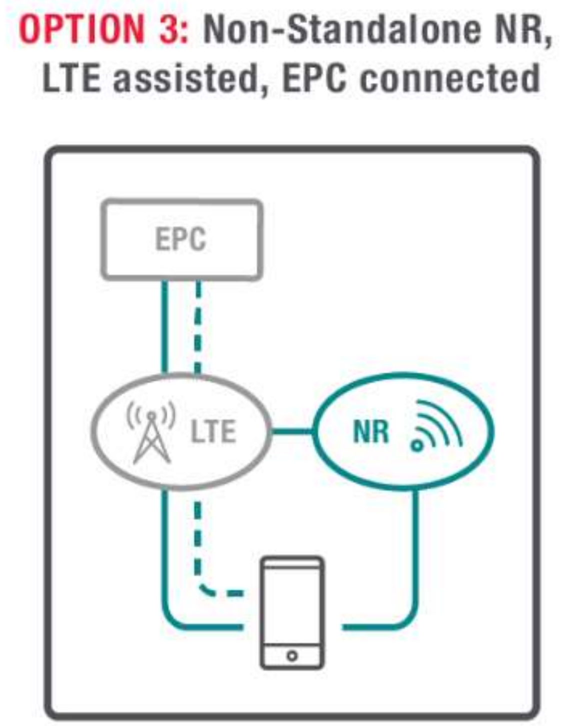
- 5G Core Network
- Enhanced LTE (eLTE)
- NR SA and NSA Combinations

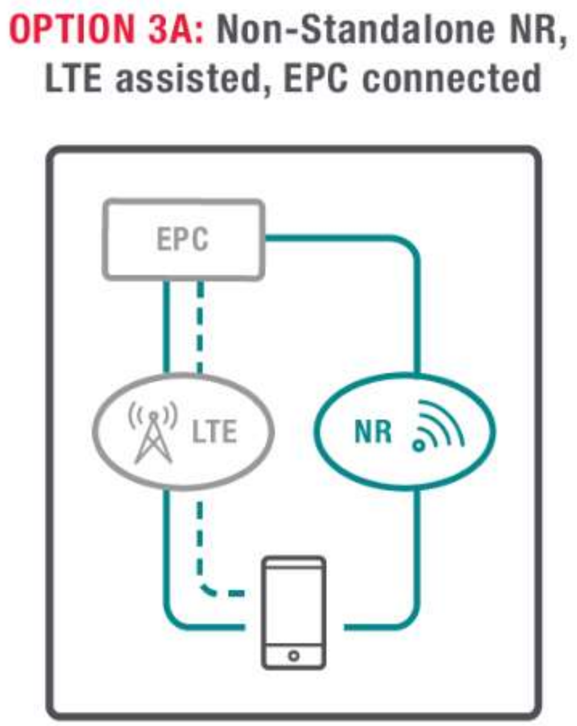
Multi-RAT Dual Connectivity with LTE Core (EPC)

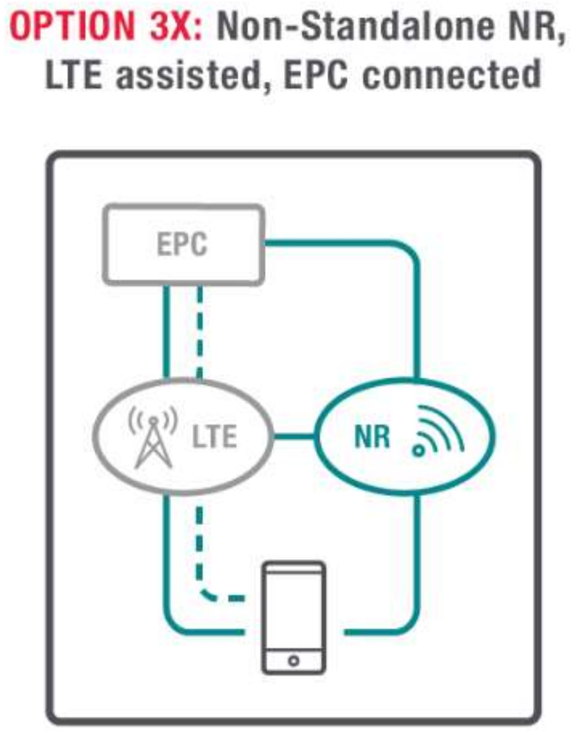
OPTIONS 3/3A/3X

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

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



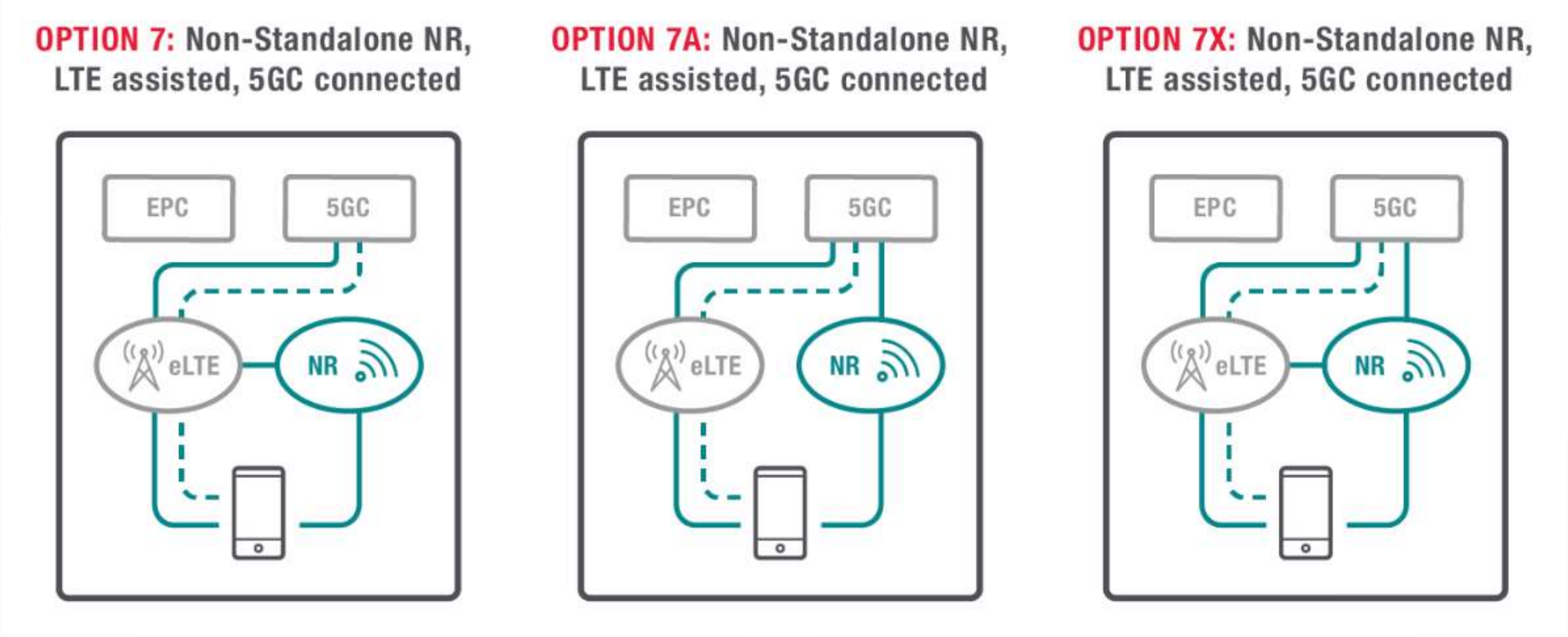




Multi-RAT Dual Connectivity with 5G Core (5GC)

OPTIONS 7/7A/7X

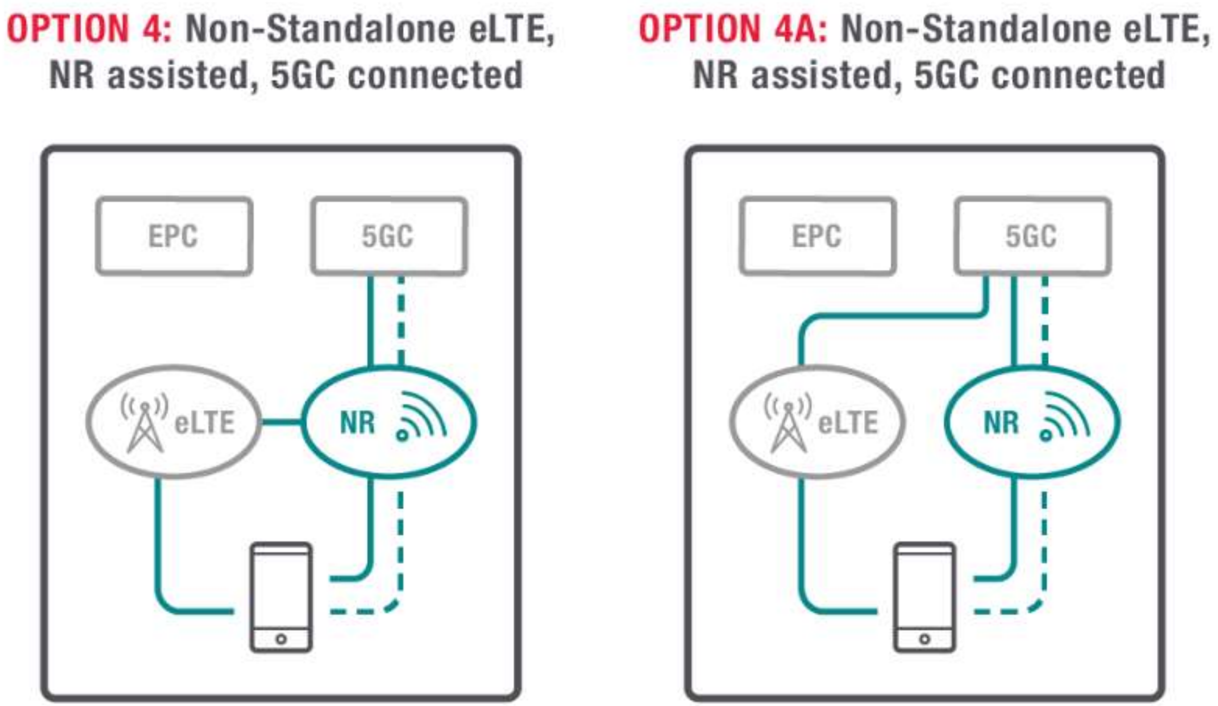
- Dual Connectivity with NG-RAN: **NG**-RAN **E**-UTRA-**NR** **D**ual **C**onnectivity (**NGEN-DC**)
  - Master Node: ng-eNB (eLTE) – eNB evolved (eLTE)
  - Secondary Node: gNB (5G NR)



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)



Carrier Aggregation & Bandwidth Adaptation

3GPP 5G Channel Bandwidth Requirements

- For FR1, 100 MHz is the maximum channel bandwidth specified
- For FR2, 50, 100, 200 and 400 MHz channel bandwidths are specified

3GPP TS 38.521-1 Table 6.1-1

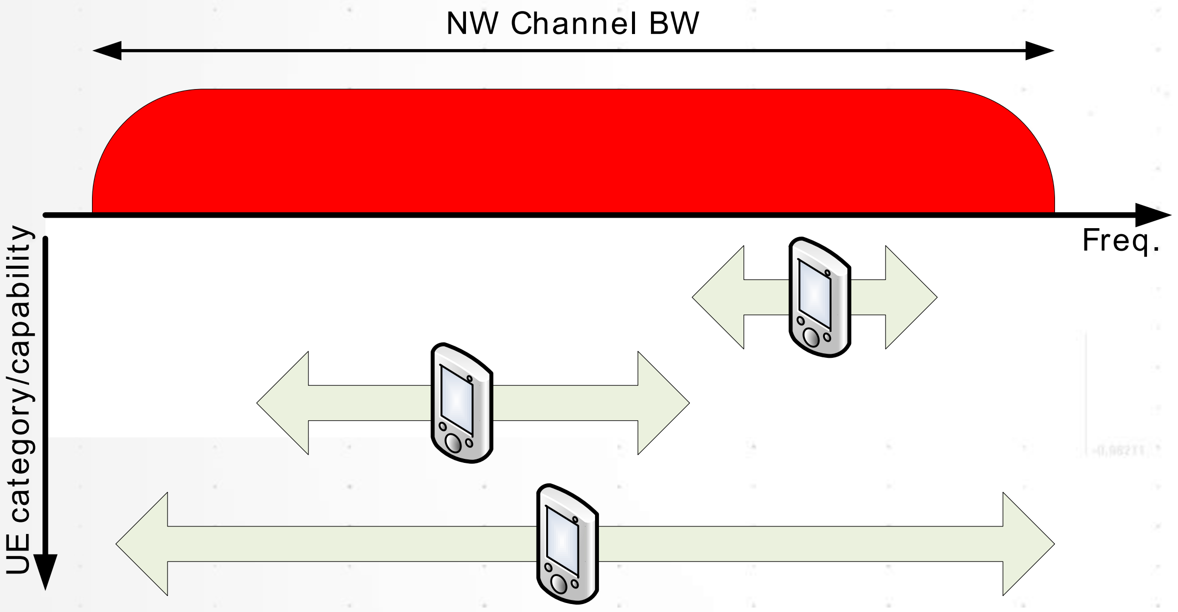
Channel Bandwidth
5 MHz
10 MHz
15 MHz
20 MHz
25 MHz
30 MHz
40 MHz
50 MHz
60 MHz
80 MHz
100 MHz

3GPP TS 38.521-2 Table 5.3.5-1

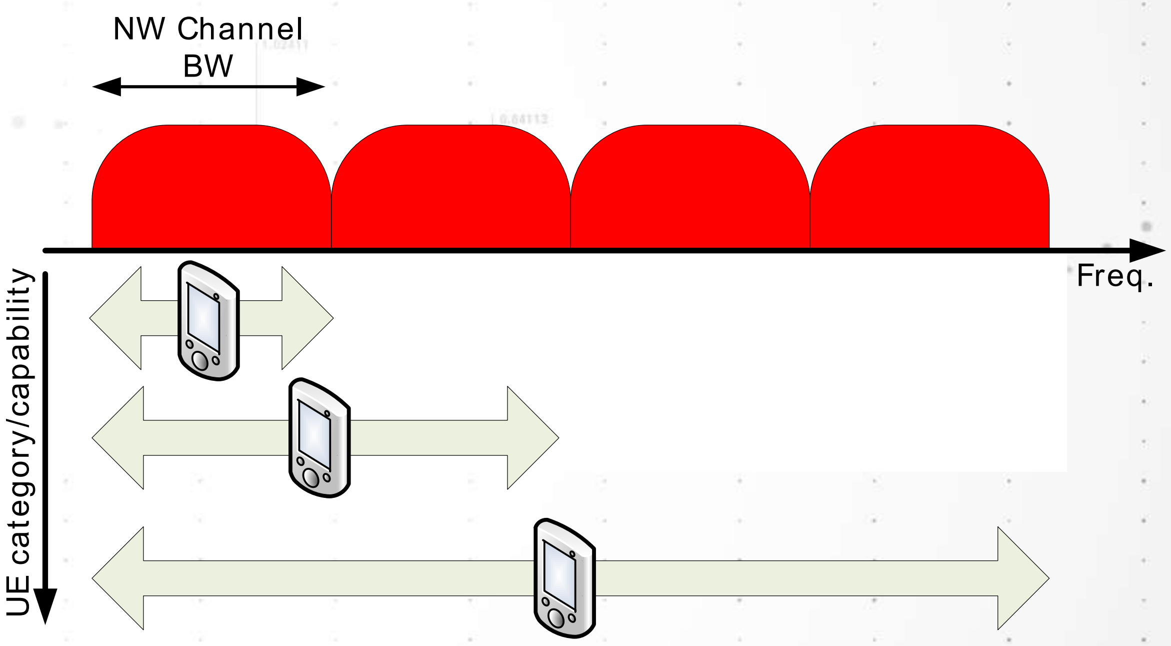
NR Band / SCS / UE Channel Bandwidth					
NR Band	SCS kHz	50 MHz	100 MHz	200 MHz	400 MHz
n257	60	Yes	Yes	Yes	N/A
	120	Yes	Yes	Yes	Yes
n258	60	Yes	Yes	Yes	N/A
	120	Yes	Yes	Yes	Yes
n260	60	Yes	Yes	Yes	N/A
	120	Yes	Yes	Yes	Yes

Single-Carrier and Multi-Carrier Operation

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



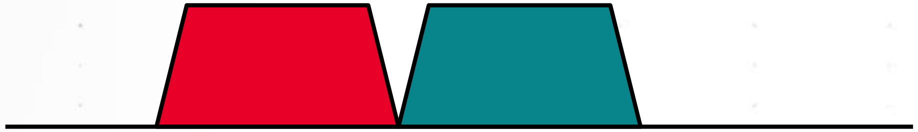
Single-Carrier Operation



Multi-Carrier Operation

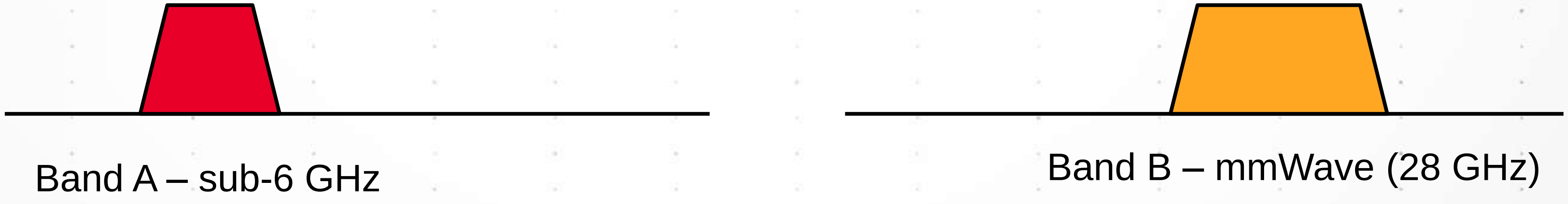
Carrier Aggregation Types

- Component Carriers may be in the same band and adjacent



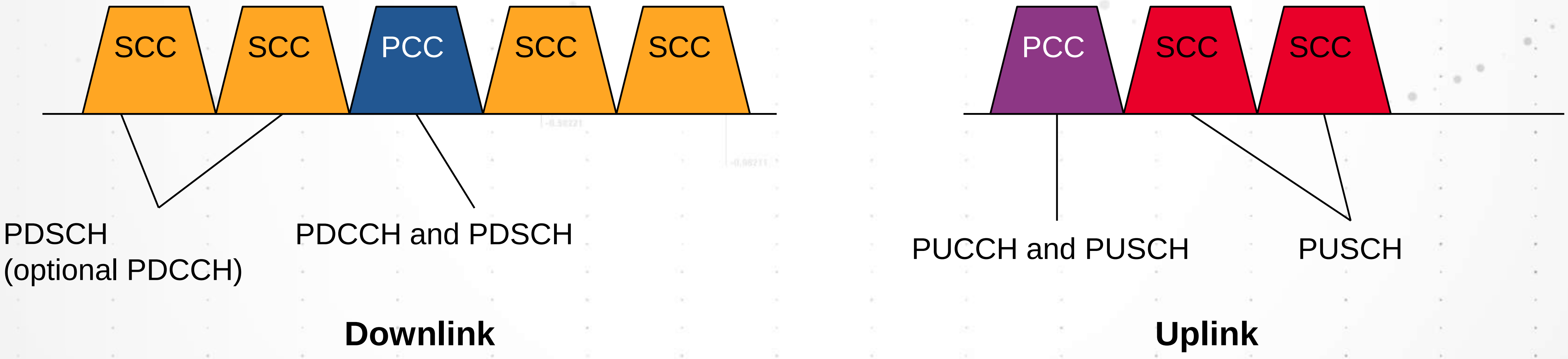
- Or they could be in the same band, non-contiguous

- Or in different bands



Channel Allocation

- RRC Connection and Registration only performed on Primary Component Carrier (PCC)
- Control channels (PDCCH and PUCCH) on Primary CC
- Data channels (PDSCH and PUSCH) on all component carriers



5G NR - Resource Allocation Unit

CORESET 38.211 - 7.3.2.2

	Description
Resource Element (RE)	Same as LTE: the smallest unit of the resource grid is made up of one SC in frequency domain and one OFDM symbol in time domain
Physical Resource Block (PRB)	12 subcarriers (same in every numerology)
Resource Element Group (REG)	One REG is made up of one PRB in frequency domain and one OFDM symbol in time domain
REG Bundles	REG bundle = X * REGs
Control Channel Element (CCE)	CCE = X * REG bundles
Control Resource Set (CORESET)	A CORESET is made up of multiple PRBs in frequency domain and 1, 2 or 3 OFDM symbols in time domain

Both frequency region and time domain region of a coreset can be defined by RRC signaling message (38.331 v15.1.0)

Bandwidth Part

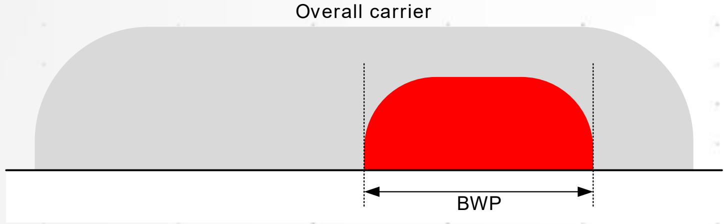
CONTIGUOUS PHYSICAL RESOURCE BLOCKS (PRBS)

- 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
- <u>One</u> or <u>multiple</u> bandwidth part configurations for each component carrier can be semi-statically signaled to a UE
  - <u>**Only one BWP**</u> in DL and one in UL <u>**is active**</u> 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

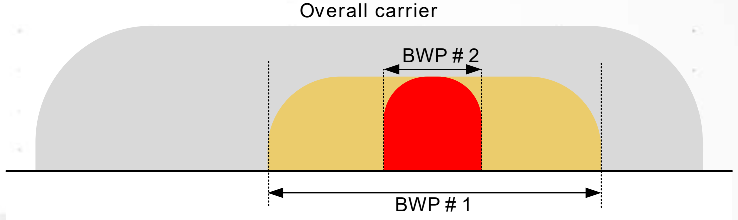
Bandwidth Part

BANDWIDTH PART USE CASES

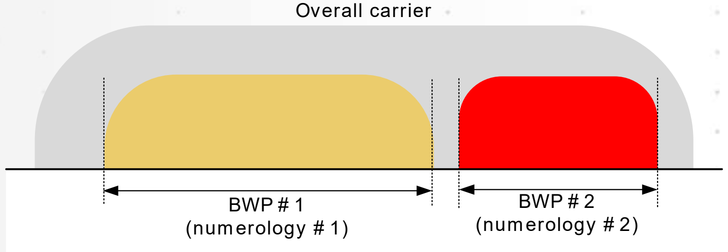
1. Supporting Reduced UE Bandwidth Capability



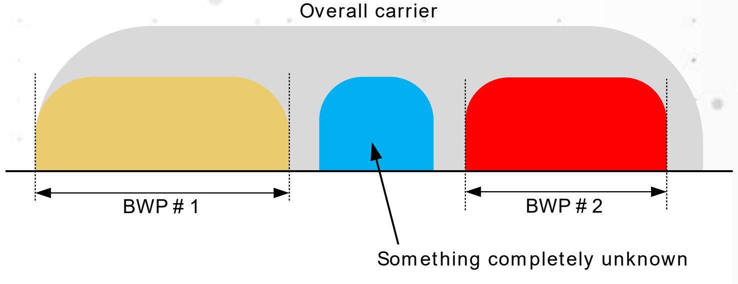
2. Supporting Reduced UE Energy Consumption



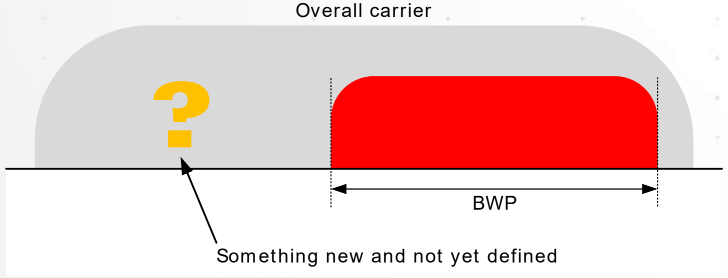
3. Supporting Different Numerologies



4. Supporting Non-contiguous Spectrum



5. Supporting Forward Compatibility

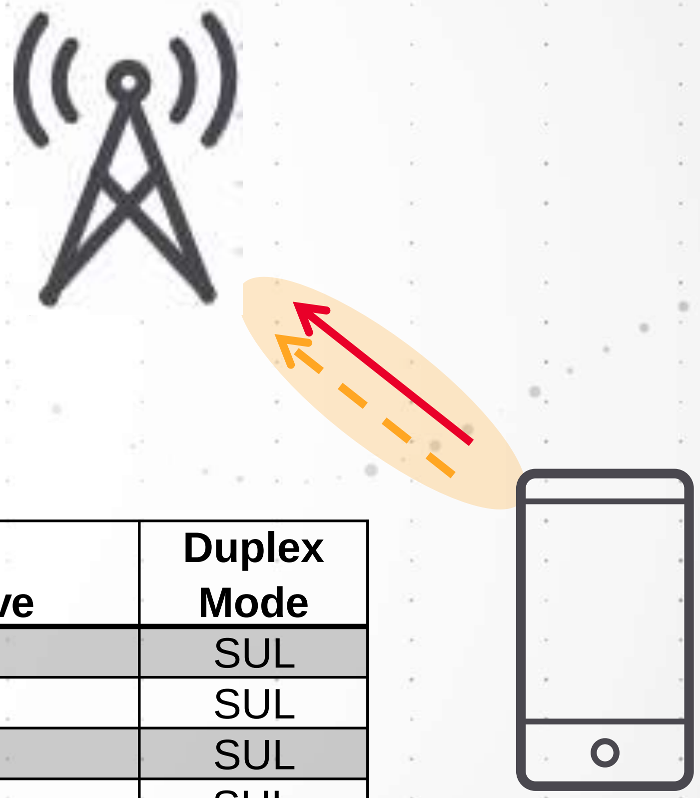


BWP activation/deactivation:

- UE may be configured with up to 4 DL and 4 UL bandwidth parts
- Activation by dedicated RRC signaling
- Activation/deactivation by DCI with explicit indication
- Activation/deactivation by a timer for a UE to switch its active DL BWP to a default BWP

Supplemental Uplink

- The UE may be configured with additional **supplemental uplink**
  - An additional **lower frequency band** UL carrier
  - Enhances data rate and deployment range in NSA mode
  - Improve performance at cell edge in SA mode
- Supplemental uplink is different from carrier aggregation because the UE may transmit on
  - The supplemental uplink OR
  - UL component carrier
    (but not on both at the same time)



Operating Band	Uplink (UL) BS Receive / UE Transmit	Downlink (DL) BS Transmit / UE Receive	Duplex Mode
n80	1710 – 1785 MHz	N/A	SUL
n81	880 – 915 MHz	N/A	SUL
n82	832 – 862 MHz	N/A	SUL
n83	703 – 748 MHz	N/A	SUL
n84	1920 – 1980 MHz	N/A	SUL
n86	1710 – 1780 MHz	N/A	SUL

Waveforms & Modulations

Waveform, Multiple Access & Coding

Waveform:

- Downlink: CP-OFDM
- Uplink: CP-OFDM + DFT-s-OFDM (Discrete Fourier Transform spread OFDM)
  - CP-OFDM targeted at high throughput scenarios
  - DFT-s-OFDM targeted at power limited scenarios

Multiple Access:

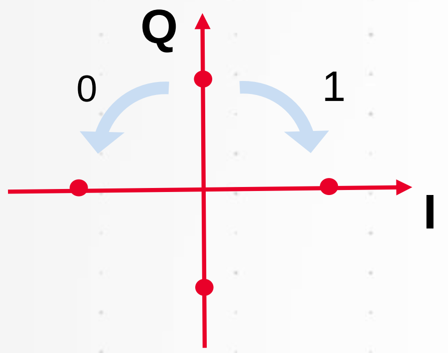
- Orthogonal Multiple Access (OFDMA)
- *Non-Orthogonal Multiple Access (NOMA) not supported in Rel-15, but being considered in Rel-16*

Coding:

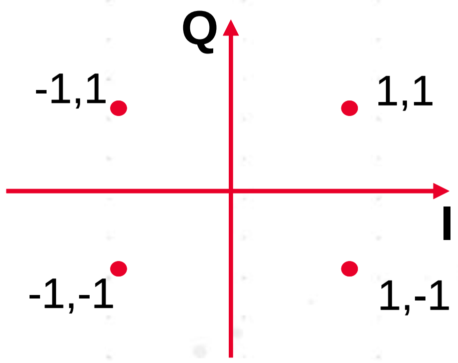
- Orthogonal Multiple Access (OFDMA)
- Network selects coding scheme to match instantaneous channel conditions
  - Optimization of capacity with a reasonable BLER
  - Reduction of latency but possibly lower throughput rate (some methods take longer to encode)
- eMBB Traffic - Low Density Parity Check (LDPC)
- PBCH & Control - Polar Code

Modulation Schemes

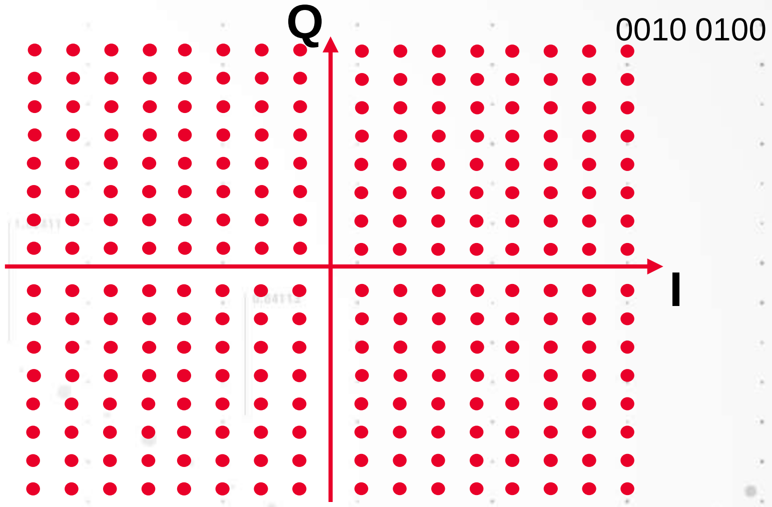
π/2-BPSK - 1 bit per symbol



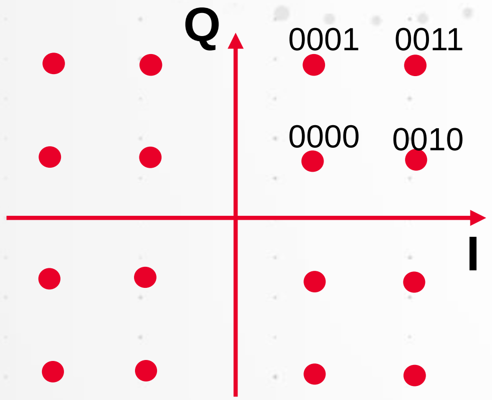
QPSK - 2 bits per symbol



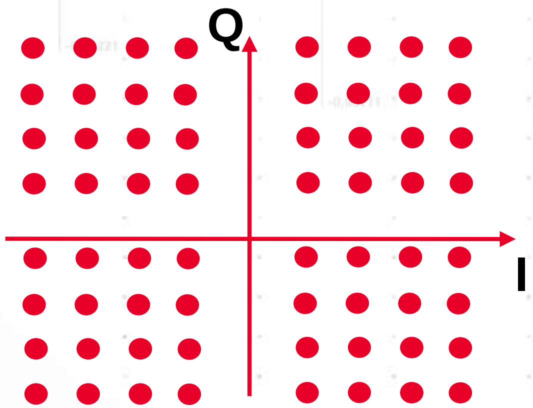
256 QAM - 8 bits per symbol



16-QAM - 4 bits per symbol



64 QAM - 6 bits per symbol



3GPP 38.101- requirements for EVM

Modulation for PDSCH	EVM %
BPSK	30
QPSK	17.5
16 QAM	12.5
64 QAM	8.0
256 QAM	3.5

Beams, Beamforming & Beam Management

Moving to mmWave Change Everything

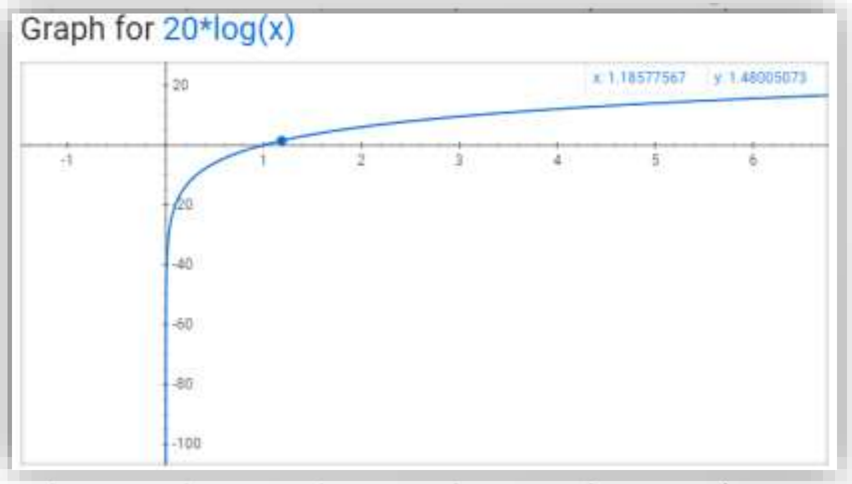
Question: Is it better to have high gain or low gain antenna?

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:

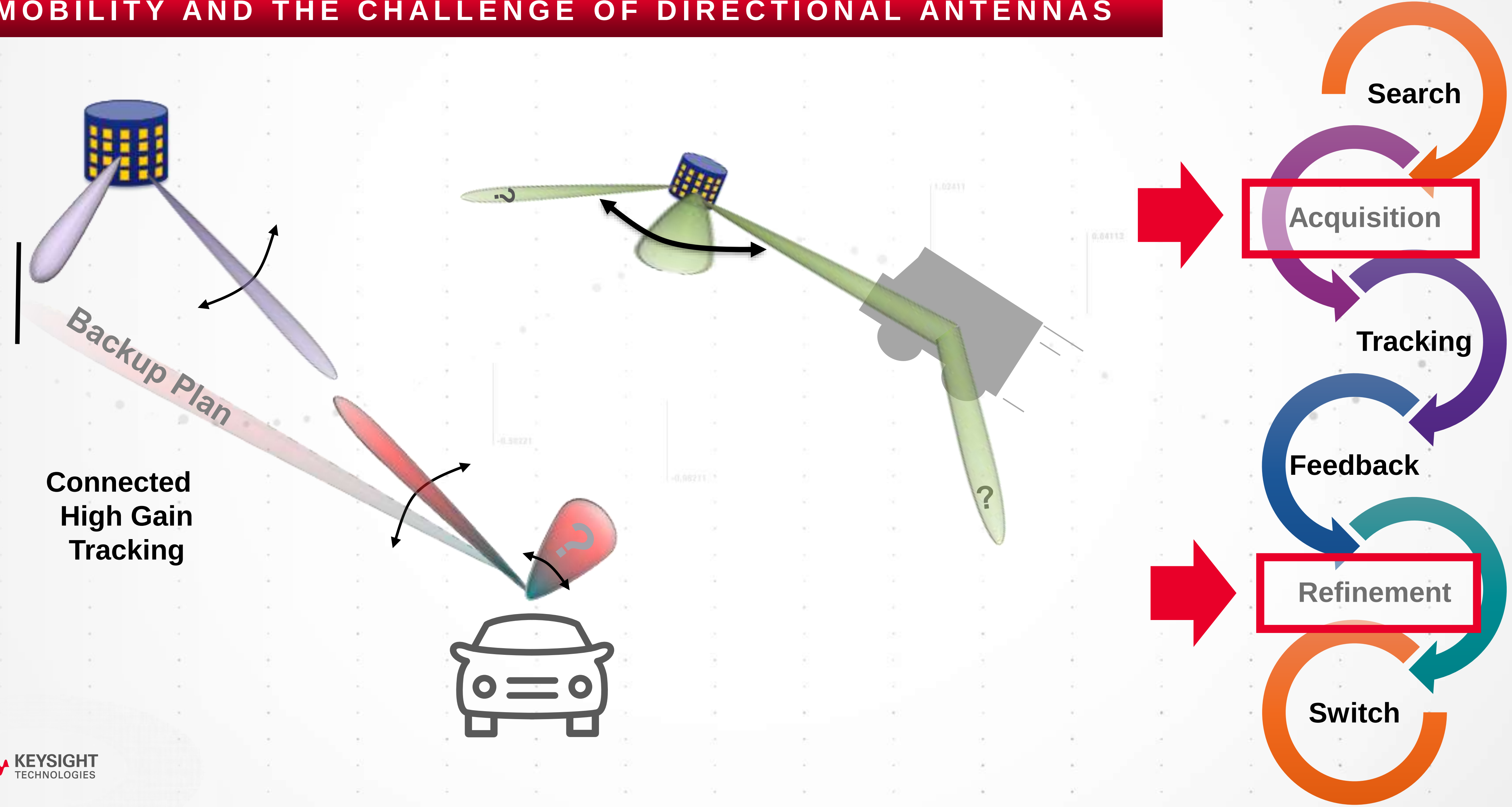
$$P_r = P_t + G_t + G_r + 20\log_{10}\left(\frac{\lambda}{4\pi R}\right)$$



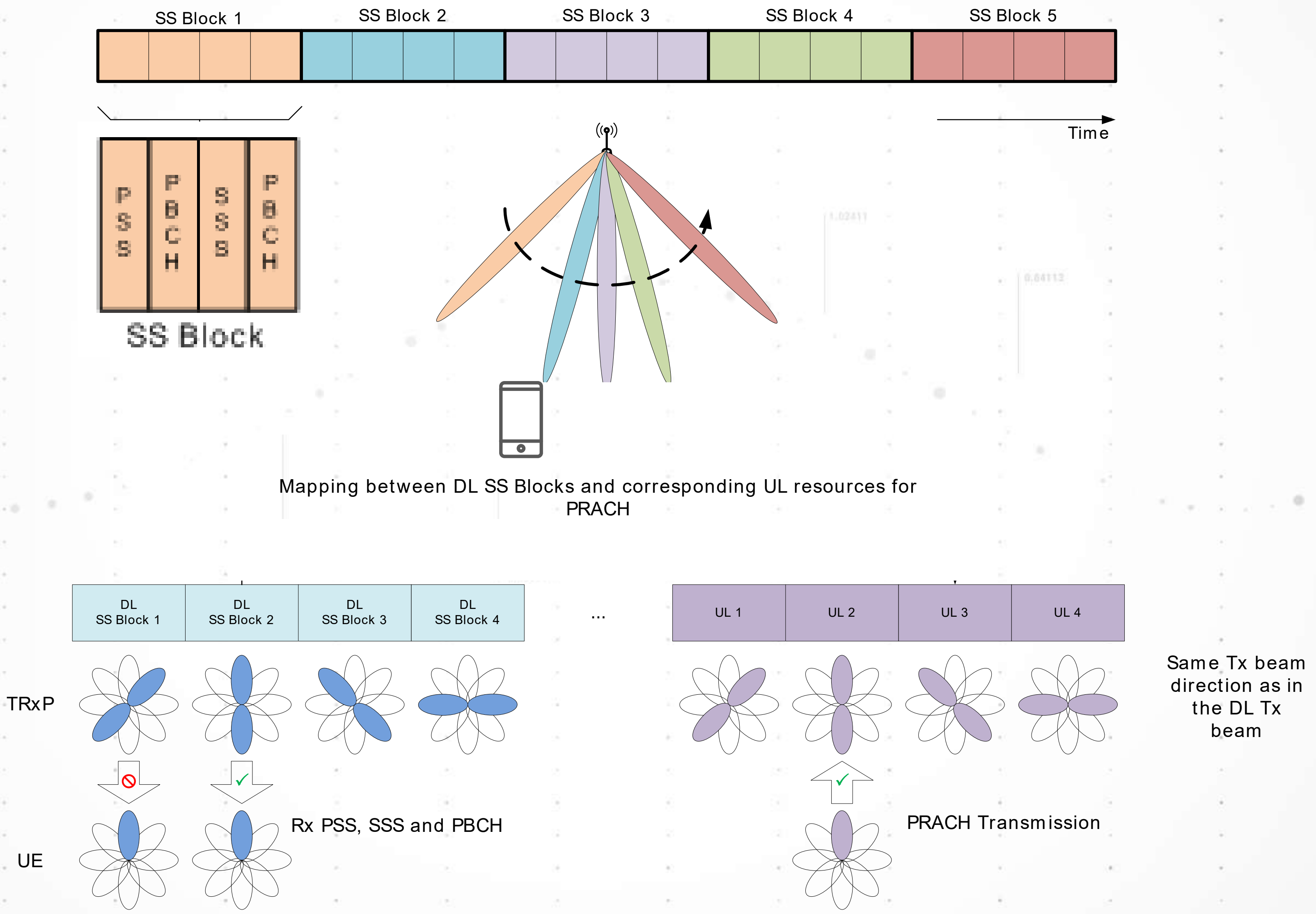
Path Loss ~ $\mathbf{f}^{2}$

New Radio mmWave Spatial Domain Optimization

MOBILITY AND THE CHALLENGE OF DIRECTIONAL ANTENNAS

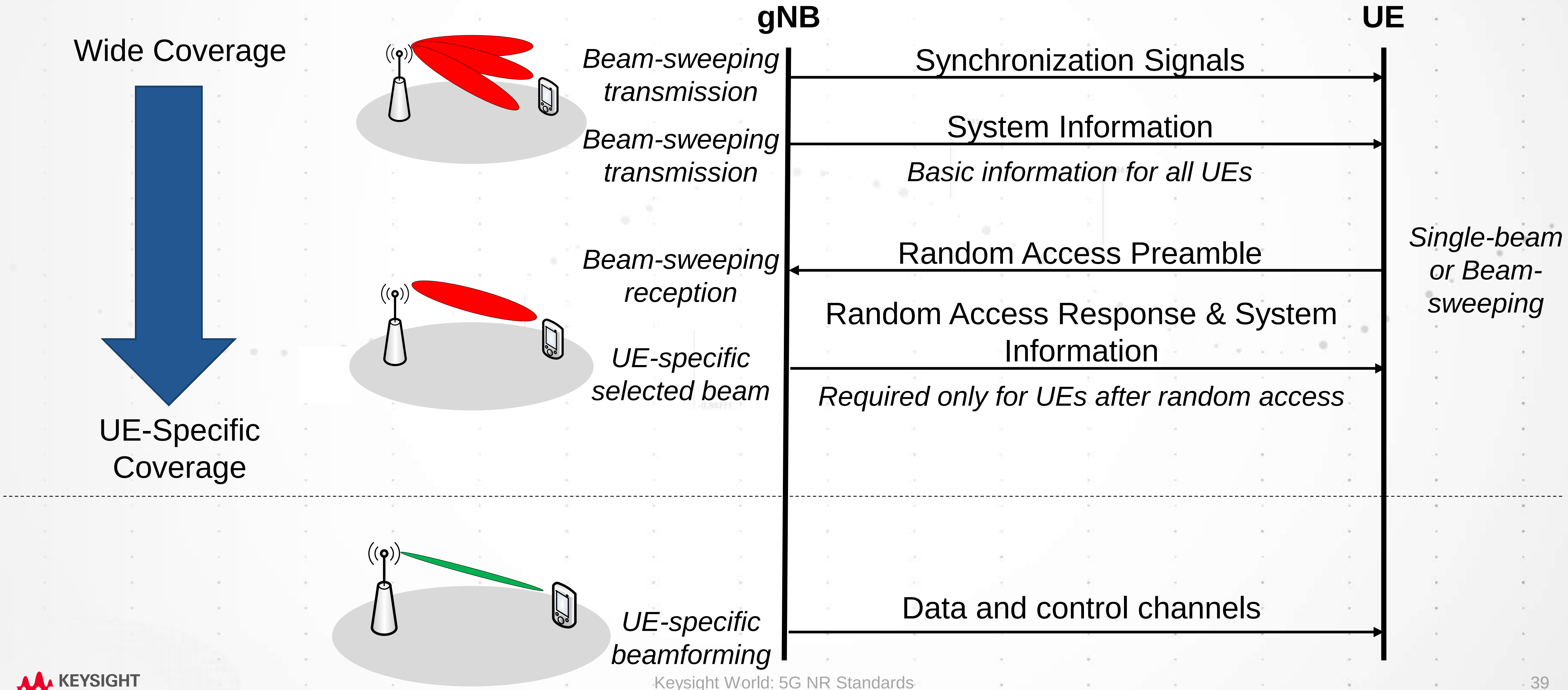


Initial Access & Beamforming: SS/PBCH Block



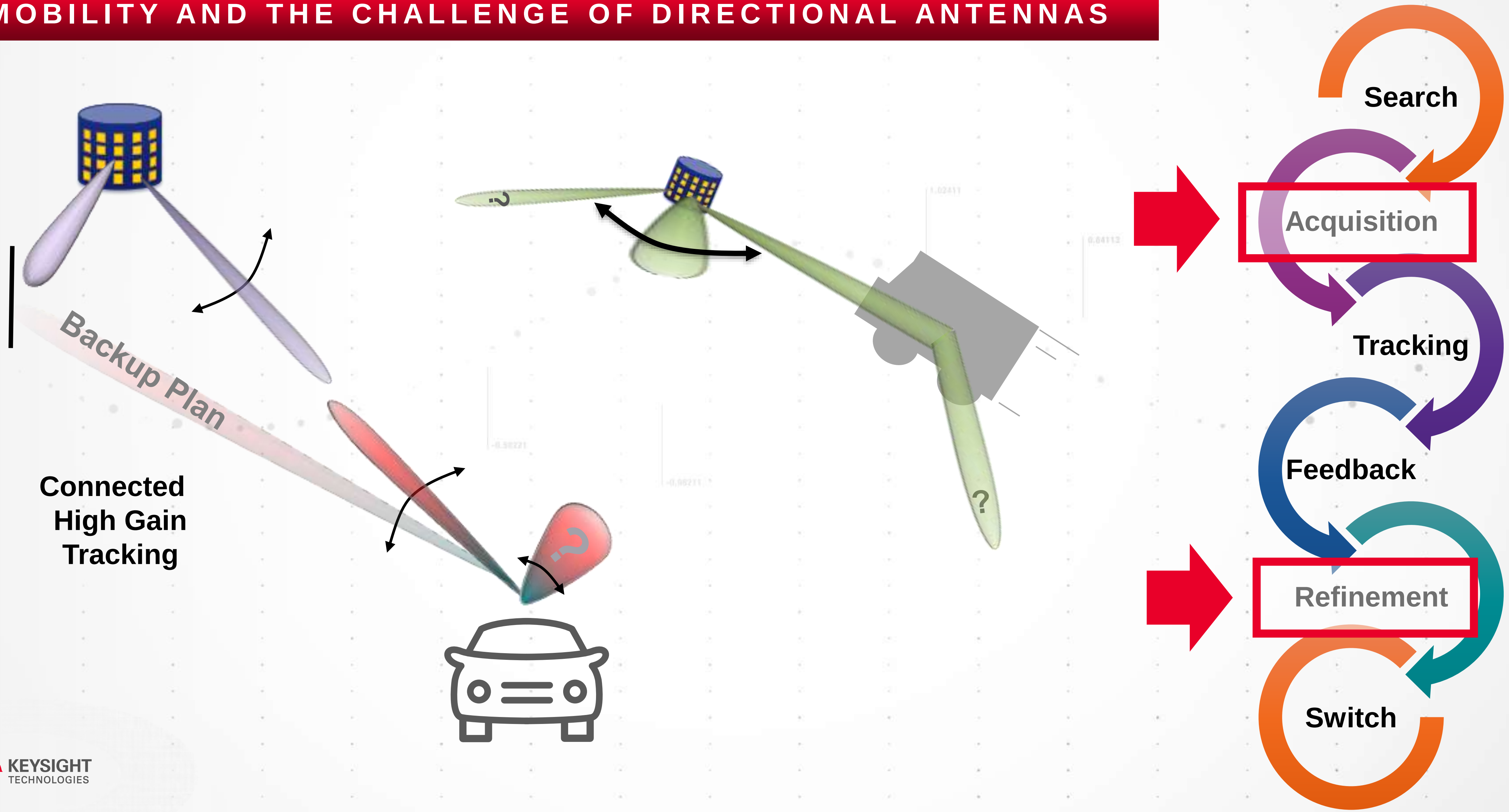
5G New Radio Initial Access

SYNCHRONIZATION, RANDOM ACCESS AND UE-SPECIFIC BEAMFORMING



New Radio mmWave Spatial Domain Optimization

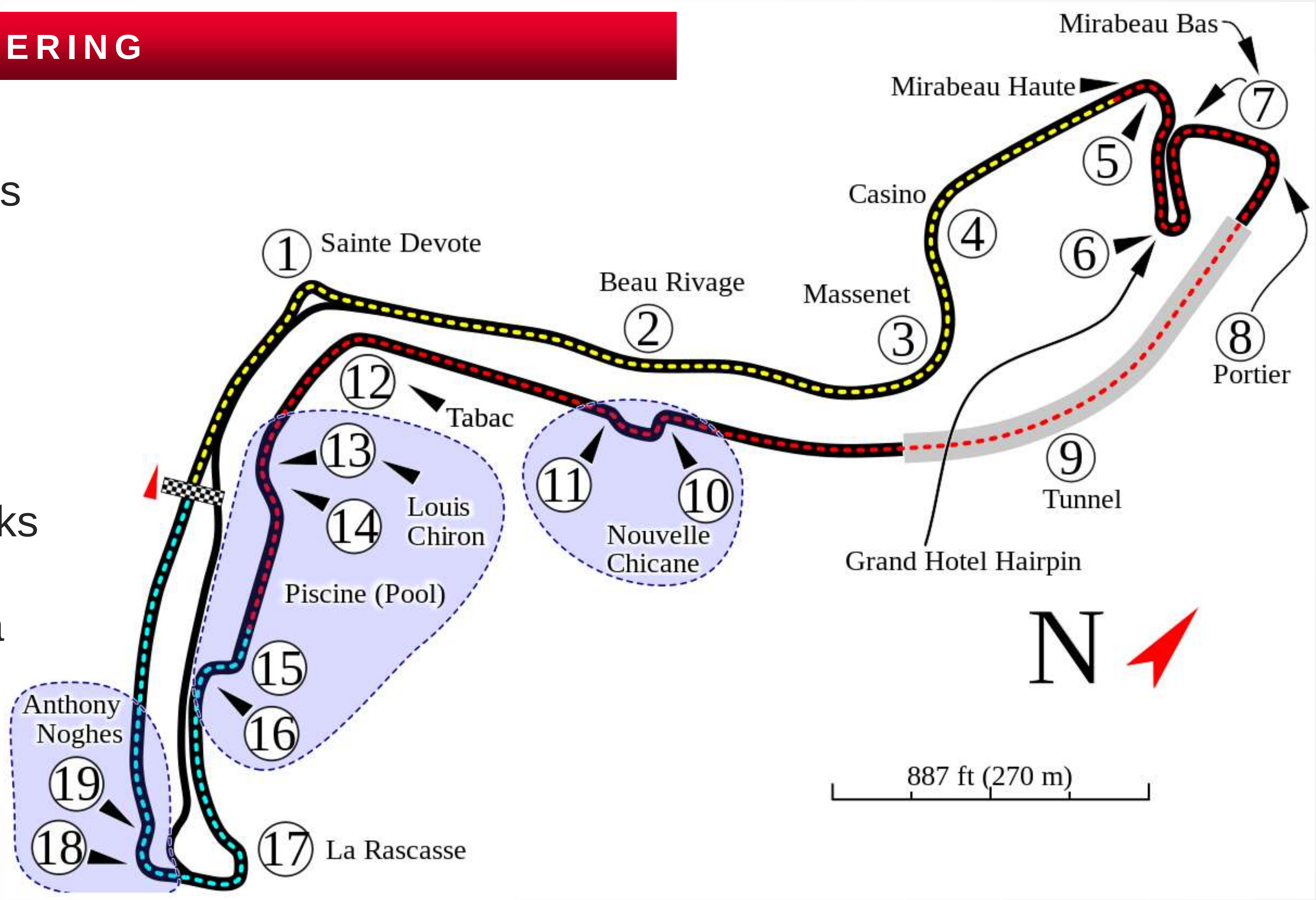
MOBILITY AND THE CHALLENGE OF DIRECTIONAL ANTENNAS



Initial Access Beam Refinement

THE IMPORTANCE OF STEERING

- Not having beam refinement is like having a race car with no steering wheel
- It could be pointed in one direction at the race start
- But a mobile environment looks more like Monte Carlo and at each corner the car without a steering wheel would crash



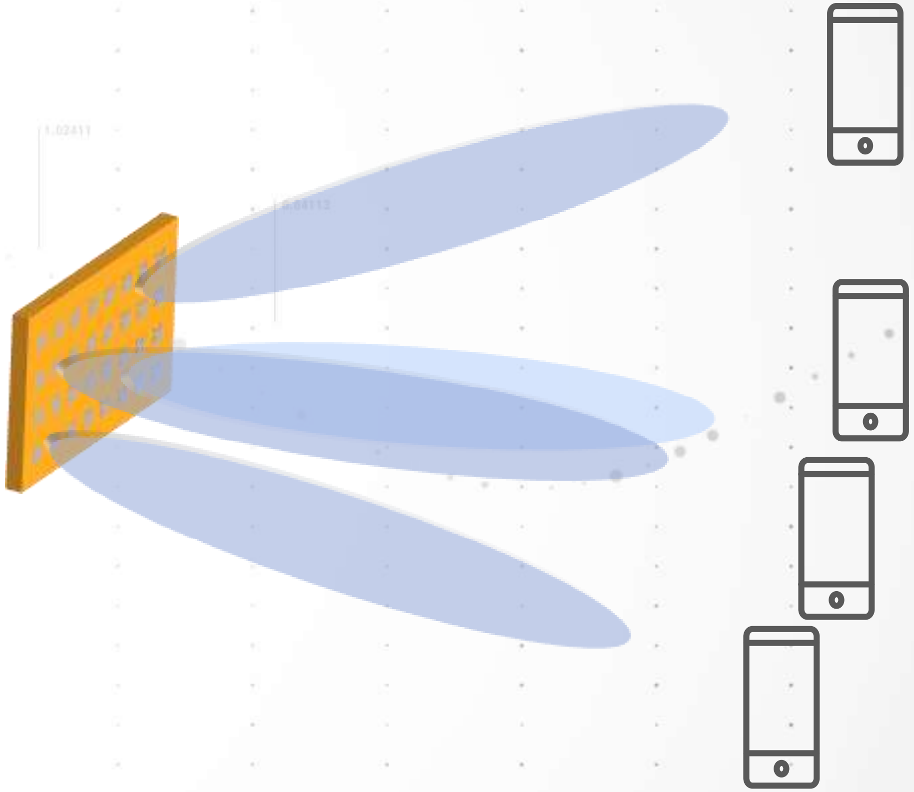
Beam Management

A set of L1/L2 procedures to acquire and maintain a set of TRxP(s) and/or UE beams that can be used for DL and UL transmission/reception, which include at least the following aspects:

- Beam sweeping: operation of covering a spatial area, with beams transmitted and/or received during a time interval in a predetermined way
- Beam determination: for TRxP(s) or UE to select its own Tx/Rx beam(s)
- Beam measurement: for TRxP(s) or UE to measure characteristics of received beamformed signals
- Beam reporting: for UE to report information of beamformed signal(s) based on beam measurement
- Beam refinement (in connected state only)

To Conclude: Beamforming/Management

- The network and device will use beamforming antennas (maybe as low as 12 degrees?)
- Narrow beams increase the received power (Signal-to-Noise) level
- Beams to different UEs can re-use the same time and frequency resources
- All common and dedicated channels are transmitted (and received) over beams
- Beams are bilateral for (t, f, (x,y,z)) – TDD operation only



To Conclude: 5G Operation at mmWave Frequencies

- mmWave has great potential (spectrum!)
- mmWave signals do not bend around corners (diffract) and are easily blocked or attenuated
- mmWave signals do bounce (reflect) readily giving rise to local scattering (multipath)
- mmWave signals act more like light rays so can be directed using special antennas
- Path loss through the air is much greater at mmWave than at LTE bands
- Changing from 1 GHz to 28 GHz path loss increases by 28 dB over 1 m

Cables are lossy and expensive, galvanic connectors may not be exposed/available, 3GPP requires FR2 tests to be radiated

Therefore, testing will be mostly performed over the air

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)

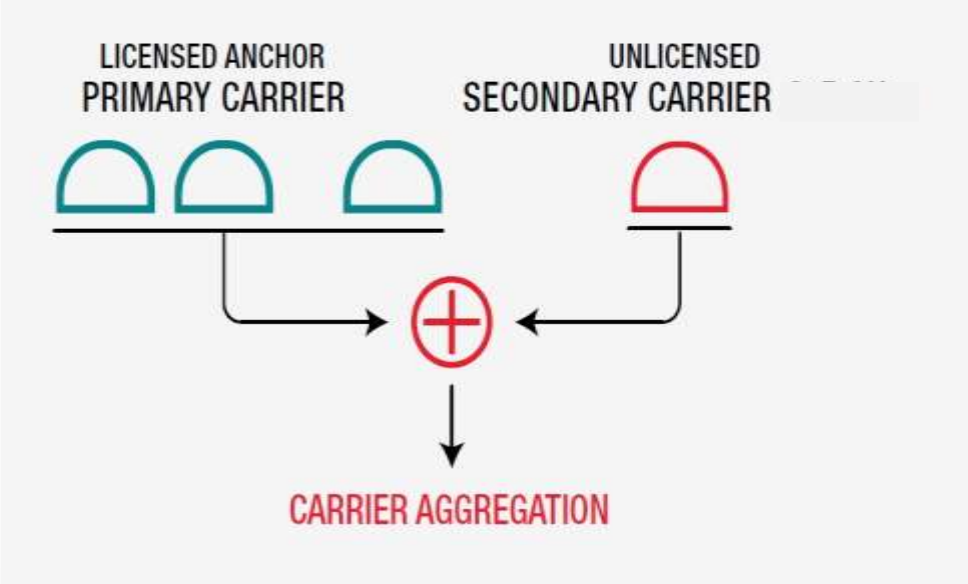
Rel-16: Unlicensed Spectrum

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

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

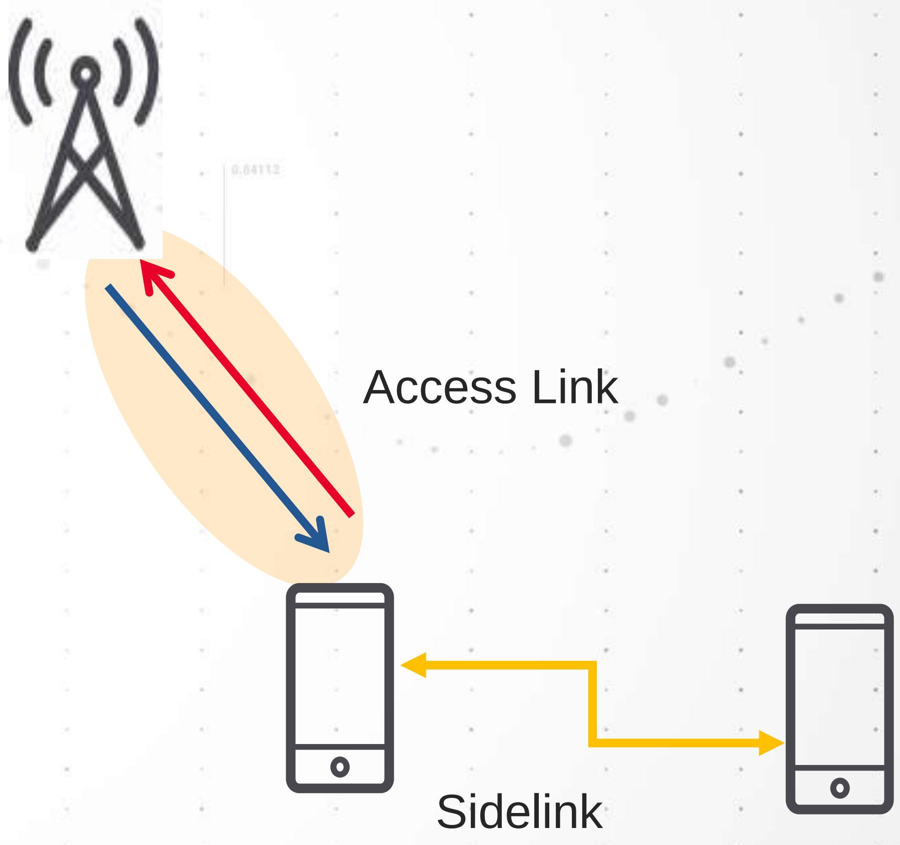
V2X: USE CASES

- Software Update
- Real-Time Situational Awareness & High-Definition Map
- Vulnerable Road User (VRU)
- Platooning
- Cooperative Maneuvers of Autonomous Vehicles for Emergency Situations
- Remote Automated Driving Cancellation (RADC)
- Automated Intersection Crossing
- Autonomous Vehicles Parking by Remote Driving
- High Definition Sensor Sharing

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

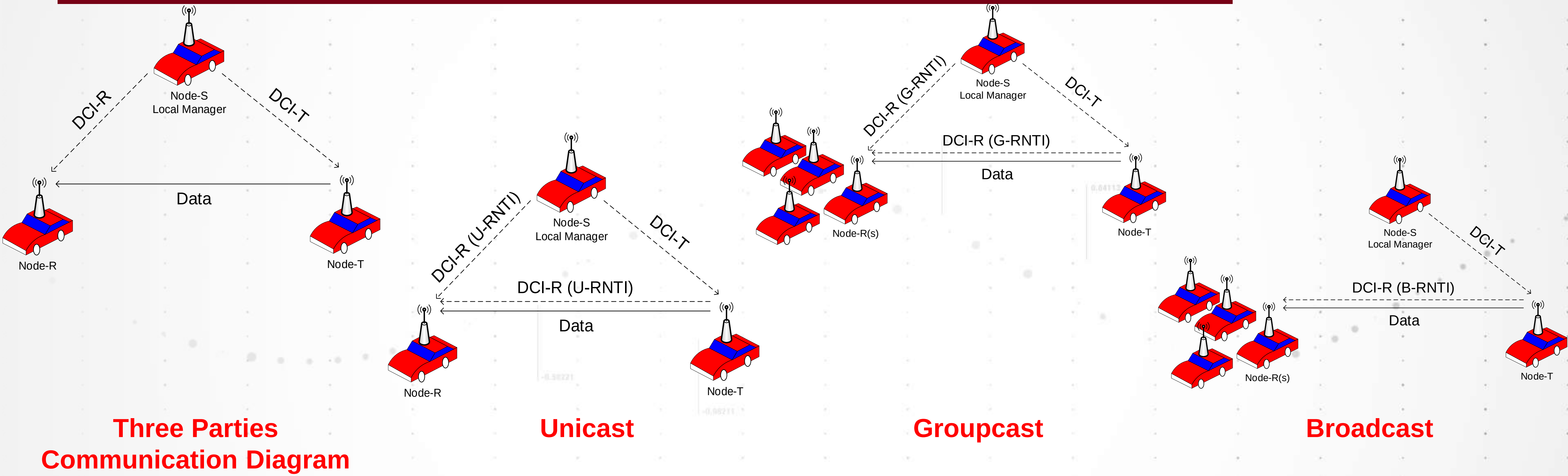
V2X (SI→WI): SIDELINK

- 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): BROADCAST, GROUPCAST AND UNICAST DEFINITION

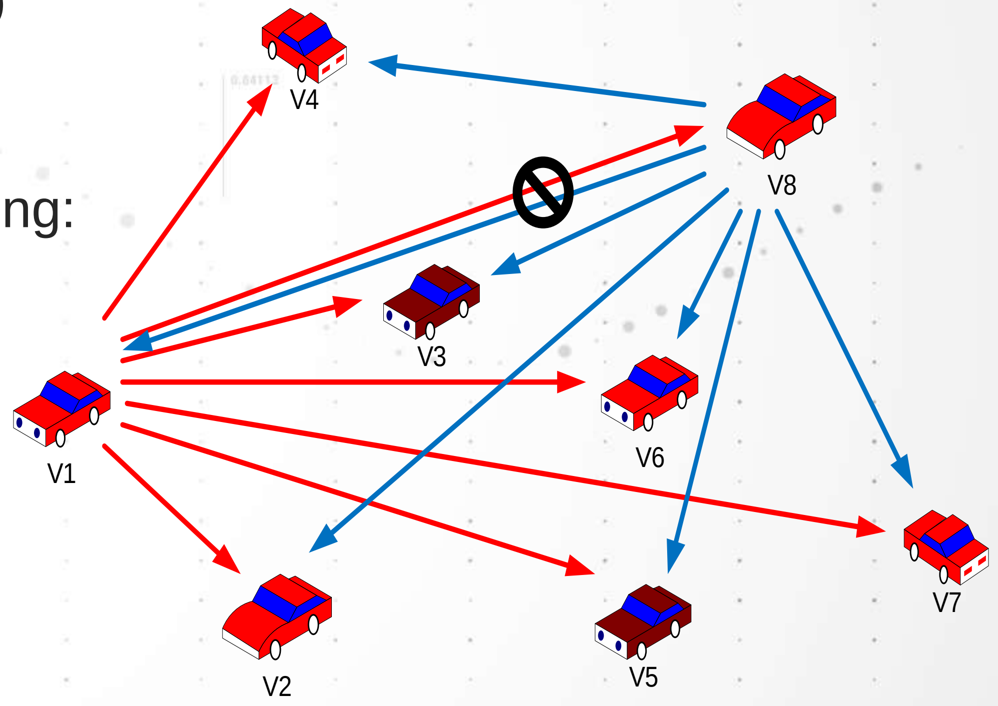


- Node-S can be gNB/eNB or another vehicle.
- Function of Node-S is to coordinate the resource usage within a local area

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

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

Keysight 5G Solutions for All Parts of the Ecosystem

5G Network Test

- Drive Test and Analytics
- UE Emulation & Load Test
- Network Simulation & 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 OTA Test
- Manufacturing Test Automation

Questions and Resources

- 3GPP Webpage www.3gpp.org
- Keysight Solutions www.keysight.com/find/5G
- Testing 5G NR Device OTA Throughput
  Download Application Note
- Copy of these slides
  www.keysight.com/find/5GBootCampPresentations

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