

5G NSA(Rel.15) 기술 및 융합서비스 워크숍

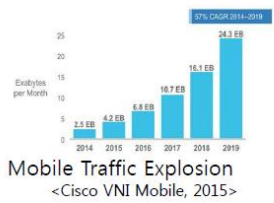
# 3GPP 5G Radio 표준기술 Overview

2018/1/4

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## 5G Main Drivers, Use Cases, KPIs

### 5G Main Drivers



Immersive Multimedia

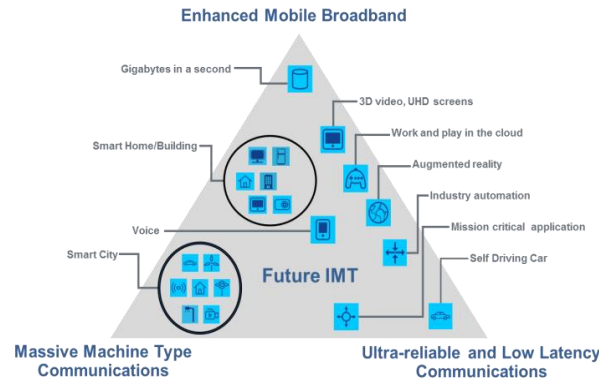


New IoT Application

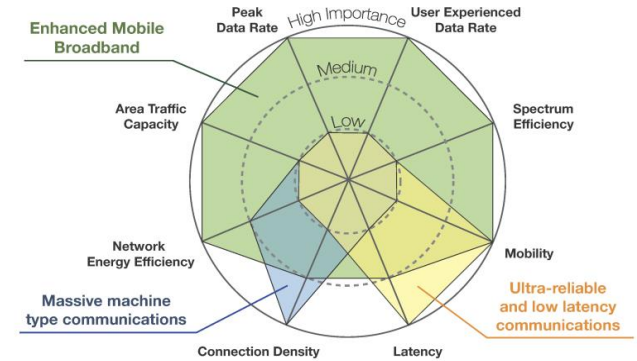


Massive Device Connectivity

### 5G Use Cases



### 5G Main KPIs



New Spectrum Utilization Demand


Support of both below 6GHz and above 6GHz

**3GPP**  
(~Rel-15/16)

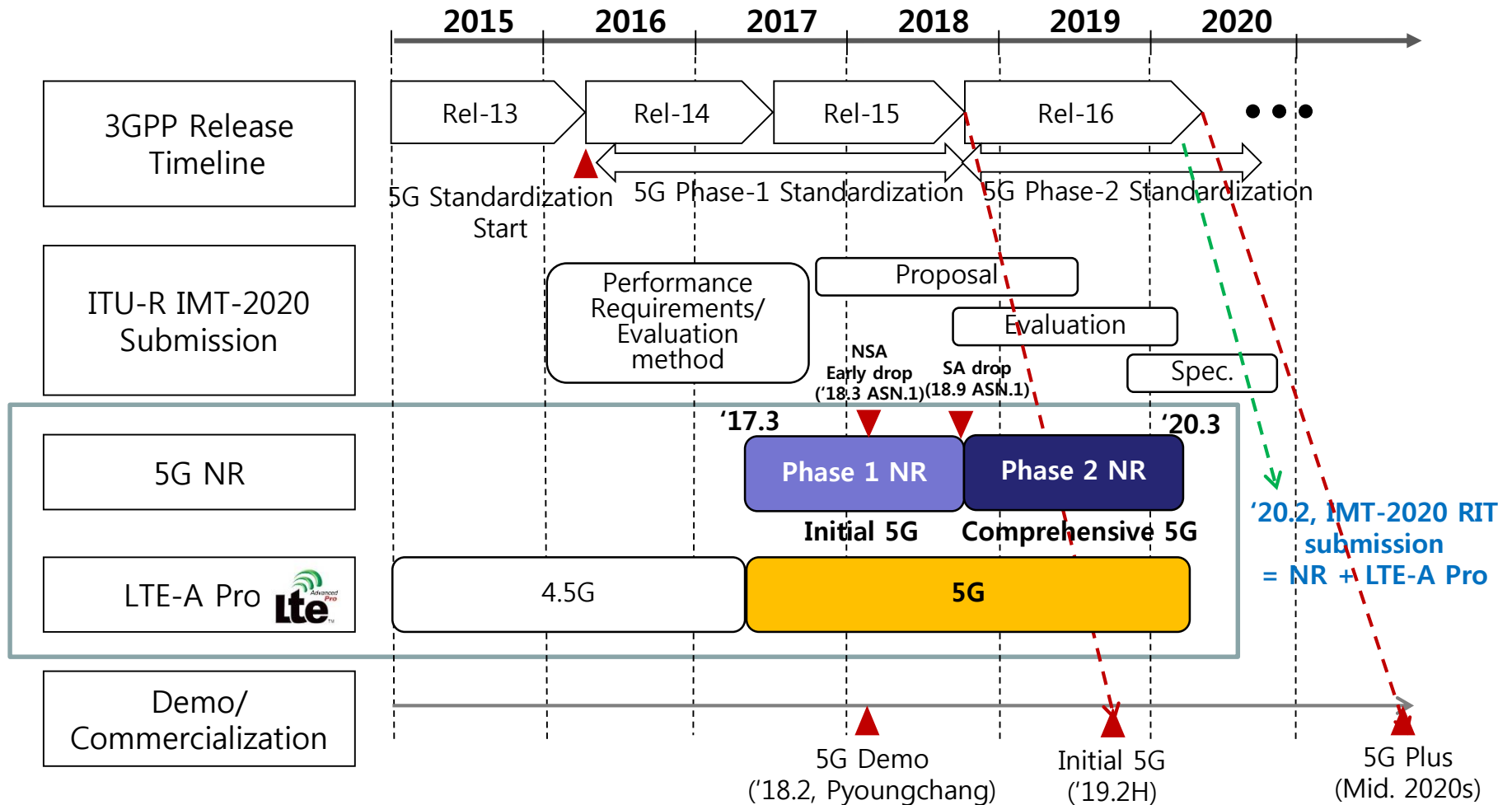
Forward Compatible Solution Requirements

Support of Challenging 5G KPIs & Use Cases

5G는 '무선 전송 성능 강화'와 '다양한 IoT 서비스 최적 실현'을 목표로 '19년 후반부터 상용화를 목표로 하는 차세대 이동통신 시스템

Issues	Discussion/Decision
<b>IMT-2020 Submission</b>	<ul style="list-style-type: none"><li>• 3GPP submission to <b>IMT 2020 (a.k.a 5G)</b> will include<ul style="list-style-type: none"><li>✓ <b>New Radio of 5G, a.k.a NR</b></li><li>✓ <b>Evolution of LTE-Advanced Pro</b></li></ul></li><li>• Submission Format<ul style="list-style-type: none"><li>✓ <b>SRIT</b> (component RIT of NR and E-UTRA/LTE)<ul style="list-style-type: none"><li>▪ <b>Component RIT: NR</b> (TBD incl. NB-IoT, eMTC)</li><li>▪ <b>Component RIT: EUTRA/LTE</b> (incl. standalone LTE, NB-IoT, eMTC, and LTE-NR DC)</li></ul></li><li>✓ <b>NR RIT only</b></li></ul></li></ul>
<b>5G Brand Name</b>	<ul style="list-style-type: none"><li>• <b>'5G' is brand name of 5G specifications</b> published by 3GPP</li><li>• <b>New '5G' logo</b> has been determined</li></ul> <div data-bbox="1058 808 1168 915" data-label="Image"></div> <ul style="list-style-type: none"><li>• <b>Which specifications?</b><ul style="list-style-type: none"><li>✓ <b>36 series and 38 series from Rel-15 and onwards for radio specifications</b></li></ul></li></ul>
<b>Spec Terminology</b>	<ul style="list-style-type: none"><li>• <b>Radio Access</b><ul style="list-style-type: none"><li>✓ <b>E-UTRA</b>: name of LTE radio access</li><li>✓ <b>NR</b>: name of new Radio</li></ul></li><li>• <b>RAN</b><ul style="list-style-type: none"><li>✓ <b>E-UTRAN</b>: a RAN that connects to EPC</li><li>✓ <b>NG-RAN</b>: a RAN that connects to 5G-CN (needs to be confirmed)</li></ul></li><li>• <b>5G-CN</b></li></ul>

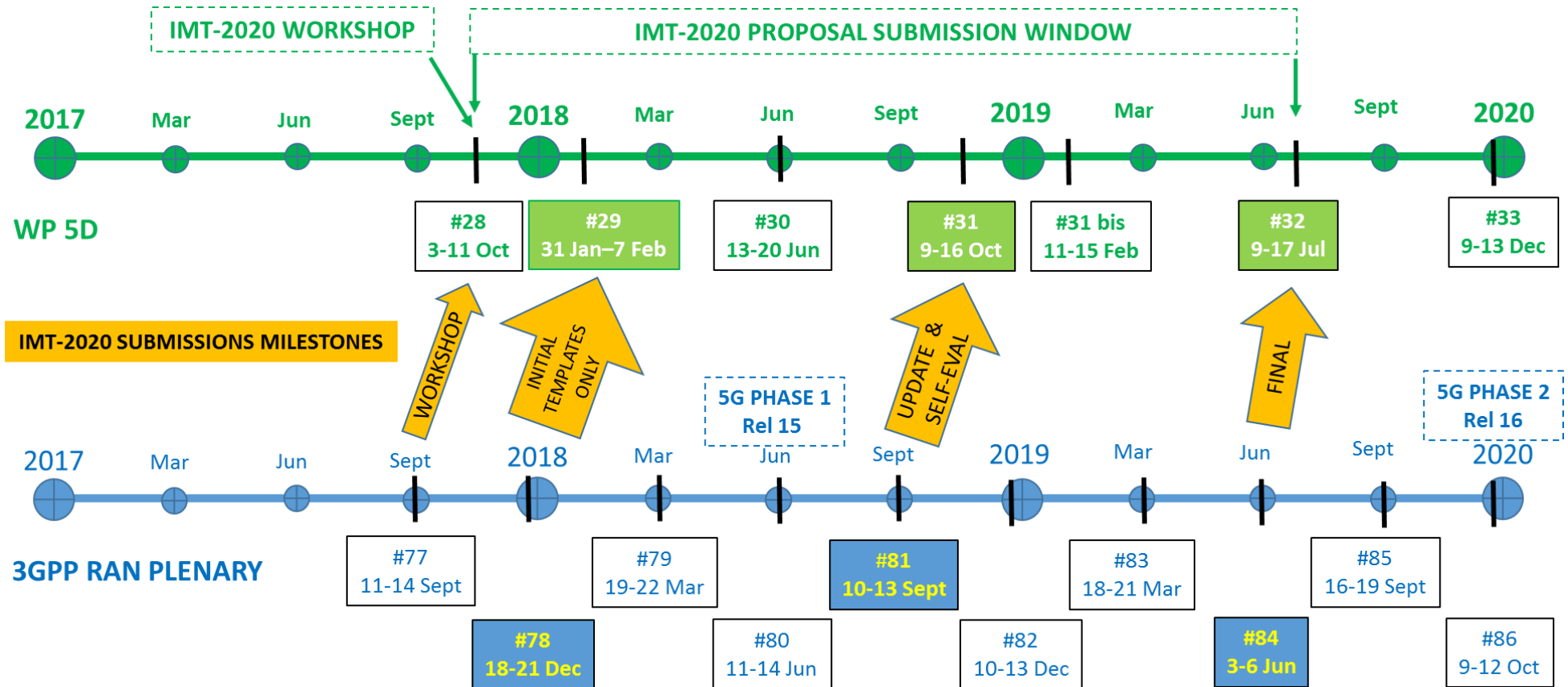
# 5G overall timeline in 3GPP



## Phased NR Approach

- **Phase 1: Rel-15**
  - ✓ NSA NR early drop : stage 3 freezing in '17.12 (ASN.1 freezing in '18.3)
  - ✓ SA NR drop: stage 3 freezing in '18.6 (ASN.1 freezing in '18.9)
- **Phase 2: Rel-16**
  - ✓ Comprehensive 5G: stage 3 freezing in '19.12 (ASN.1 freezing in '20.3)

# IMT-2020 Submission Time Plan



Reference: RP-172098: 3GPP submission towards IMT-2020, ITU-R Ad-Hoc Contact person (Telecom Italia)

# 5G 'NR' 표준화 동향

## Previous works for 5G NR in 3GPP

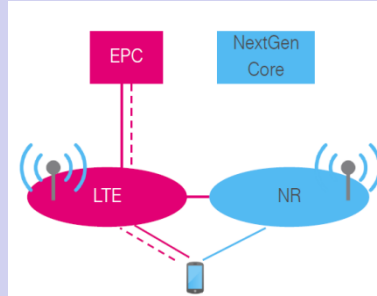
- **RAN level SI of channel modelling for frequencies above 6 GHz**
  - ✓ SI rapporteur: Samsung
  - ✓ SI was completed in '16.06
  - ✓ TR 38.900 was approved in '16.06 and now v14.3.1 is available
- **RAN level SI of scenarios and requirements for NR**
  - ✓ SI Rapporteur: CMCC
  - ✓ SI was completed in '16.12
  - ✓ TR 38.913 was approved in '16.09 and now v14.3.0 is available
- **Technical NR study item**
  - ✓ SI Rapporteur: NTT DOCOMO
  - ✓ SID was completed in '17.03
  - ✓ TR 38.912 v14.1.0 is now available

## Ongoing works for 5G NR in 3GPP

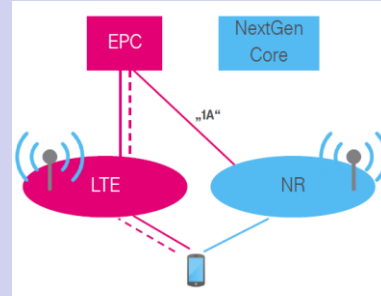
- **Phase 1 work item** started from '17.03, targeting final ASN.1 completion in '18.09
  - ✓ **ASN.1 freezing for NSA-NR is scheduled in '18.03 (stage 3 freezing in '17.12)**
  - ✓ **ASN.1 freezing for SA-NR in '18.09 (stage 3 freezing in '18.06)**
- Phase 2 study items were approved in '17.03, but actual study will begin from '18. 1Q
  - ✓ **Completion of Phase 2 work items is scheduled in '20.03**

## Target contents for Rel-15 phase 1 work item

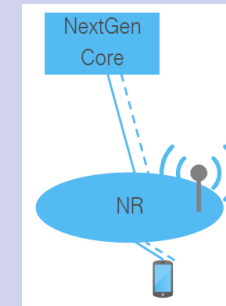
- Support for **both Standalone and Non-Standalone operation** will be included, work starting in conjunction and running together
  - ✓ NSA (Non Stand-Alone) NR in this context implies using LTE as control plane anchor
  - ✓ SA (Stand-Alone) NR in this context implies full control plane capability for NR



**NSA-NR:**  
Stage 3 completion in '17.12



Reference: RP-161266,  
Deutsche Telekom



**SA-NR:**  
Stage 3 completion in '18.6


- **NSA-NR (stage 3 completion in '17.12) : eMBB + low latency**
- **SA-NR (stage 3 completion in '18.06) : eMBB + URLLC**
- **<6GHz and >6GHz** in scope (cf. frequency above 52.6 GHz will be included in phase 2)
  - ✓ NR general, 3.5G, 4.5G, 28G, LTE (1,2,3,4,5CC)+NR (1CC), intra-band and inter-band NR

# Approved NR Study Items

## Approved 3GPP NR study items (from RAN #75)

Title	Leading WG	Rapporteur	Note
New SI: Study on NR-based Access to Unlicensed Spectrum	RAN1	Qualcomm, Ericsson, Nokia, Intel, Samsung	<6GHz, >6GHz standalone, LAA, DC
New Study Item proposal: Study on Non-orthogonal Multiple Access for NR	RAN1	ZTE, CATT, Intel, Samsung	2 step RACH out-of-scope
Study on NR to support Non-Terrestrial Networks	RAN1	Thales, Dish	Channel modeling, scenario discussion
Study on evaluation methodology of new V2X use cases	RAN1	LG, Qualcomm, DOCOMO, Intel	Evaluation methodology for V2X phase 3
New SID Proposal: Study on Integrated Access and Backhaul for NR	RAN2	Qualcomm, Samsung	In-band/out-band relay Multi-hop relay
New Study Item on Self Evaluation towards IMT-2020 submission	ITU-R AdHoc	Huawei, Ericsson, Telecom Italia	Self evaluation for IMT-2020 submission
New SID on CU-DU lower layer split for New Radio	RAN3	NTT DOCOMO	Study underway
New SID on Study on test methods for New Radio	RAN4	Intel, CATT, Qualcomm, MediaTek	OTA testing for NR above 6GHz
Study on Separation of CP and UP for split option 2 for NR	RAN3	Ericsson	Follow up normative work approved targeting a June/2018 completion

 NR phase 2 SI: put on hold, study will begin in Q1, 2018

 NR SIs now underway

# 5G 'NR' 무선 요구사항 및 물리계층 주요 요소기술

# Requirements & Scenarios [1/3]

RAN level SI of scenarios & requirements for NR

- Study item rapporteur : CMCC
- SID was approved in December, 2015
- TR 38.913 approved after RAN #73 (September, 2016)
- SI was completed in RAN #74

New Gen. Access Techs. (Target Scenarios)

	eMBB	mMTC	URLLC	eV2X	<6GHz	≥6GHz
Indoor Hotspot	■		■		■	■
Dense Urban	■				■	■
Rural					■	
Urban Macro	■		■		■	■
High Speed	■				■	■
Extreme Rural for the Provision of Minimal Services over Long Distance	■	■			■	
Urban Coverage for Massive Connection		■			■	
Highway Scenario				■	■	
Urban Grid for Connected Car				■	■	
Commercial A2G scenario	■				■	
Light aircraft scenario	■				■	
Satellite extension to Terrestrial	■	■			■	■

Exact mapping between deployment scenarios and use cases is TBD

# Requirements & Scenarios [2/3]

## New Gen. Access Techs.: Target KPIs

Peak Data Rate	DL-20Gbps UL-10Gbps	Coverage	MCL:164dB (160bps) Function of data rate
Peak Spectral Efficiency	DL-30bps/Hz UL-15bps/Hz	UE Battery Life	10y (15y is desirable)
Bandwidth	Up to IMT-2020 Requirement	UE Energy Efficiency	Qualitative
Control Plane Latency	10ms	Cell/TRP Spectral Efficiency	3x IMT-Advanced
User Plane Latency	URLLC-0.5ms eMBB-4ms	Area Traffic Capacity	Factored by SE, site density, BW
Latency for Infrequent Small Packets	No worse than 10s	User Experience Data Rate	Factored by 5% SE & BW
Mobility Interruption Time	0ms	5 <sup>th</sup> Percentile User Spectral Efficiency	3x IMT-Advanced
Inter-system Mobility	btw IMT-2020 & IMT	Connection Density	10 <sup>6</sup> devices/km <sup>2</sup>
Reliability (URLLC)	(1-10 <sup>-5</sup> ) with latency 1ms	Mobility	500km/h
Reliability (eV2X)	(1-10 <sup>-5</sup> ) with latency 2~10ms	Network Energy Efficiency	Qualitative Quantitative

## New Gen. Access Techs. (Requirements)

### Architecture & Migration

Tight interworking btw. New RAT and LTE
Support of connectivity through multi-TxPs
Flexible options for splitting the RAN architecture
Deployment flexibility e.g. to host relevant RAN, CN and application functions at the edges of the network
C-plane/U-plane separation
Deployments using Network Function Virtualization
Independent evolution of the RAN and the CN
Operation of Network Slicing
Sharing of the RAN between multiple operators

### Supplementary Services

Multimedia Broadcast/Multicast Service	
Location/Positioning Service – The NR should enable, and improve if suitable, state-of-art positioning techniques	
Critical Comm. Service	Public safety communications
	Emergency communications
	Public warning/emergency alert
V2X Communication	

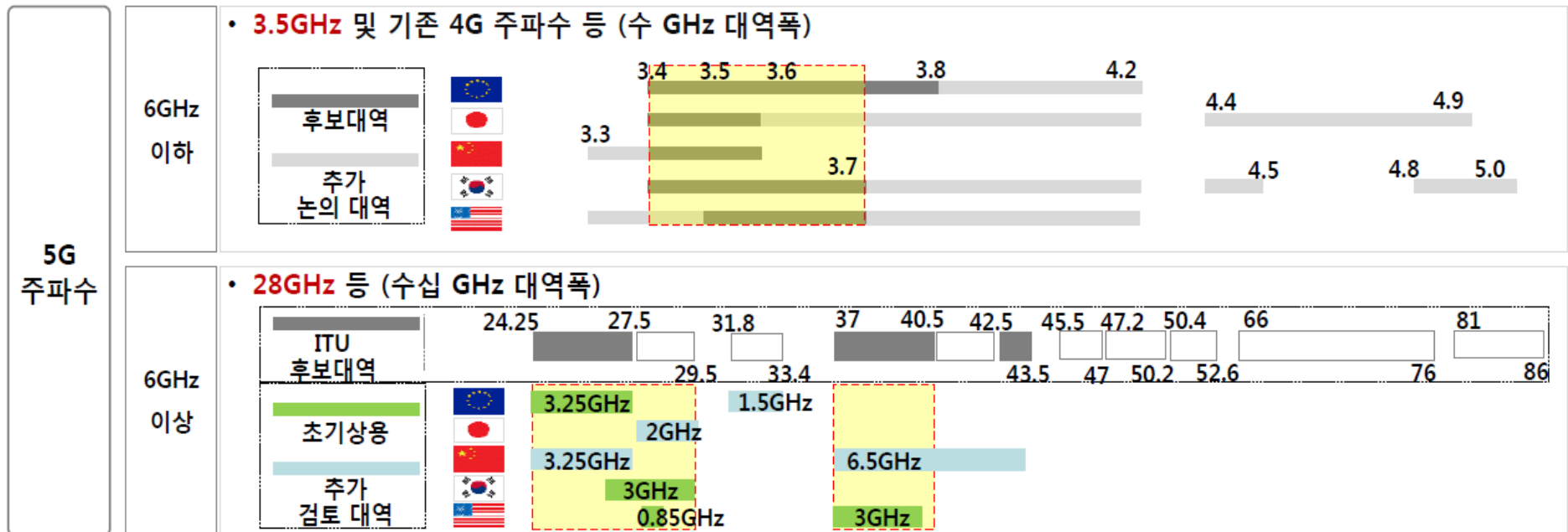
## Operational Requirement

Deployment possible in at least one identified IMT-band	Easy operation and Self Organization requirements
Channel bandwidth scalability	Complexity-related requirements
Spectrum flexibility	Cost-related requirements
Duplexing flexibility	Energy-related requirements
Support of shared spectrum	Security & Privacy related requirement relevant for Radio Access
Spectrum range: up to 100GHz	Performance monitoring and management
Support for wide range of services	Lawful Interception
Co-existence and interworking with legacy RATs	Backhaul and signaling optimization requirements
Control of EMF exposure levels requirements	Relay requirements
Interworking with non-3GPP systems	High availability
Radio Resource Management requirements	

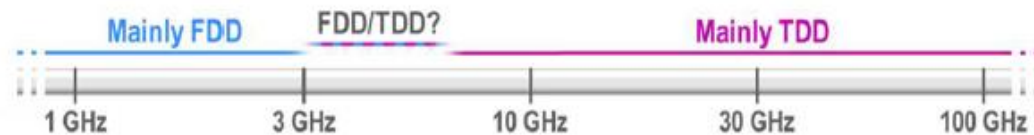
PHY Components	Major decisions
Frequency bands	<ul style="list-style-type: none"> <li>Both <b>below 6GHz</b> and <b>above 6GHz</b> (from 6GHz to 52.6GHz) support</li> </ul>
Duplexing	<ul style="list-style-type: none"> <li><b>Paired and unpaired spectrum</b> ( Dynamic TDD, FDD)</li> </ul>
Waveform & Multiple access	<ul style="list-style-type: none"> <li>DL: OFDM</li> <li>UL: OFDM-based                             <ul style="list-style-type: none"> <li>✓ CP-OFDM for eMBB for up to 40GHz,</li> <li>✓ DFT-s-OFDM - single stream transmissions (targeting for link budget limited cases)</li> </ul> </li> </ul>
Subcarrier spacing	<ul style="list-style-type: none"> <li>Subcarrier spacing dependent on NR bands                             <ul style="list-style-type: none"> <li>✓ For below 6GHz: <b>15kHz, 30 kHz</b> and 60kHz (only for URLLC) are feasible</li> <li>✓ For above 6GHz: <b>60kHz, 120kHz</b> and 240kHz (SS block subcarrier spacing) are potential candidates of feasible subcarrier spacing</li> </ul> </li> </ul>
Bandwidth	<ul style="list-style-type: none"> <li>Sub 6GHz: 5, 10, 15, 20, 25, 40, 50, 60, 80, <b>100MHz</b></li> <li>mmWave: 50, 100, 200, <b>400MHz</b></li> </ul>
Channel coding	<ul style="list-style-type: none"> <li><b>LDPC for data channel</b></li> <li><b>Polar code for control channel</b></li> </ul>
Multiple antenna	<ul style="list-style-type: none"> <li>Number of MIMO layer: 8 for DL and 4 for UL</li> <li><b>DL/UL beam management</b> supported</li> </ul>

## Wide Range of Spectrum Consideration for 5G NR

- FR1: Frequency Range < 6GHz (including re-farming bands and new bands for 5G)
- FR2: Frequency Range > 6GHz (including mmWave bands)



## Duplexing



Reference: Ericsson

## New bands for NR

E-UTRA and NR Band	Uplink (UL) band	Downlink (DL) band	Duplex mode
	BS receive / UE transmit	BS transmit / UE receive	
	$F_{UL\_low} - F_{UL\_high}$	$F_{DL\_low} - F_{DL\_high}$	
n77	3300 MHz - 4200MHz	3300 MHz - 4200MHz	TDD
n78	3300 MHz - 3800MHz	3300 MHz - 3800MHz	TDD
n79	4400 MHz - 5000MHz	4400 MHz - 5000MHz	TDD
n80 (3)	1710 - 1785 MHz	N/A	SUL
n81 (8)	880 - 915 MHz	N/A	SUL
n82 (20)	832 - 862 MHz	N/A	SUL
n83 (28)	703 - 748 MHz	N/A	SUL
n84 (1)	1920 - 1980 MHz	N/A	SUL
n85 (41)	2496 - 2690 MHz	N/A	SUL
...			
n257	26.5GHz - 29.5GHz	26.5GHz - 29.5GHz	TDD
n258	24.25GHz-27.5GHz	24.25GHz-27.5GHz	TDD
n259	N/A	N/A	TDD
n260	37 - 40 GHz	37 - 40 GHz	TDD

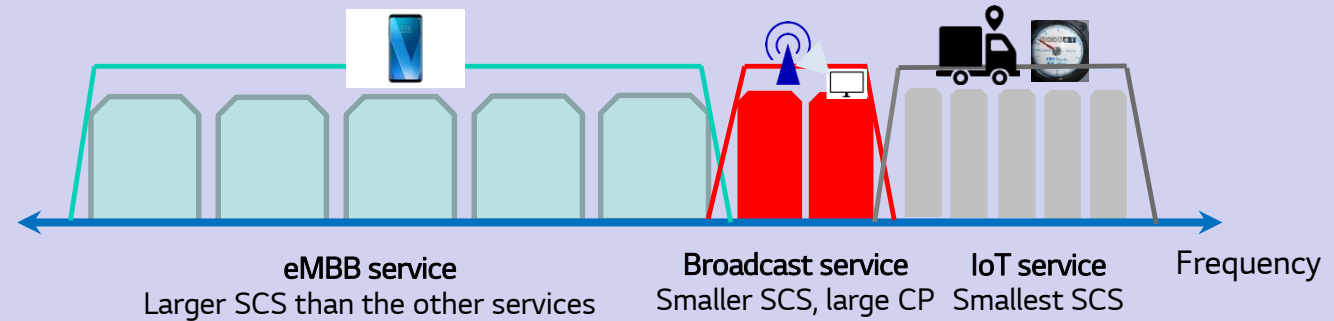
## Re-farming bands for NR

Band number	UL	DL	Duplex mode
n1	1920 – 1980 MHz	2110 – 2170 MHz	FDD
n2	1850 – 1910 MHz	1930 – 1990 MHz	FDD
n3	1710 – 1785 MHz	1805 – 1880 MHz	FDD
n5	824 – 849 MHz	869 – 894MHz	FDD
n7	2500 – 2570 MHz	2620 – 2690 MHz	FDD
n8	880 – 915 MHz	925 – 960 MHz	FDD
n20	832 – 862 MHz	791– 821MHz	FDD
n28	703 – 748 MHz	758 – 803 MHz	FDD
n38	2570 – 2620 MHz	2570 – 2620 MHz	TDD
n41	2496 – 2690 MHz	2496 – 2690 MHz	TDD
n50	1432 – 1517 MHz	1432 – 1517 MHz	TDD
n51	1427 – 1432 MHz	1427 – 1432 MHz	TDD
n66	1710 – 1780 MHz	2110 – 2200 MHz	FDD
n70	1695 – 1710 MHz	1995– 2020 MHz	FDD
n71	663 – 698 MHz	617 – 652 MHz	FDD
n74	1427 – 1470 MHz	1475 – 1518 MHz	FDD
n75	N/A	1432 – 1517 MHz	SDL
n76	N/A	1427 – 1432 MHz	SDL

## NR Downlink

- Unified waveform and multiple access design across all services

- ✓ Waveform: CP-OFDM
- ✓ Multiple Access: OFDMA



## NR Uplink

- Different waveforms and multiple access schemes optimized for different deployments

- ✓ Macro cell / wide Area : SC-OFDM + SC-FDMA as in LTE systems today for PAPR reduction
- ✓ Small cell / local area : CP : CP-OFDM + OFDMA to maximize spectral efficiency

## Scalable BW based on $2^k$ subcarrier spacing

- Operation in mmWave bands with wider BW
  - OFDM subcarrier spacing should be scalable with the channel BW so that FFT size scales such that processing complexity does not increase exponentially for wider BWs

### Outdoor and macro coverage

FDD/TDD < 3 GHz



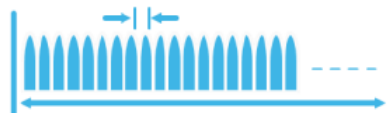
e.g. 1, 5, 10 and 20 MHz

Subcarrier spacing  
e.g. 15 kHz

Reference: Qualcomm

### Outdoor and small cell

TDD > 3 GHz



e.g. 80/100 MHz

Subcarrier spacing  
e.g. 30 kHz

### Indoor wideband

TDD e.g. 5 GHz (Unlicensed)



e.g. 160MHz

Subcarrier spacing  
e.g. 60 kHz

### mmWave

TDD e.g. 28 GHz



e.g. 500MHz

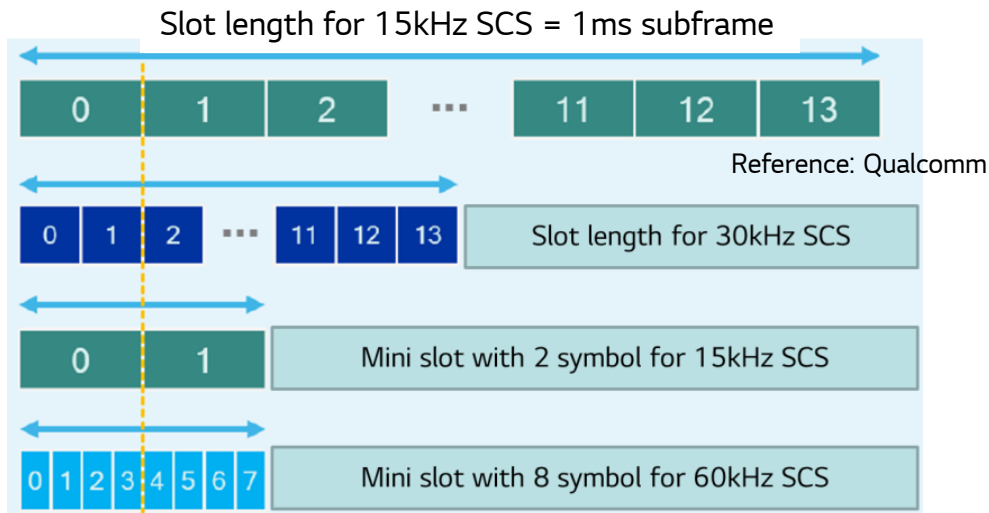
Subcarrier spacing, e.g. 120 kHz

## Numerology (SCS, CP length) & slot structure for NR

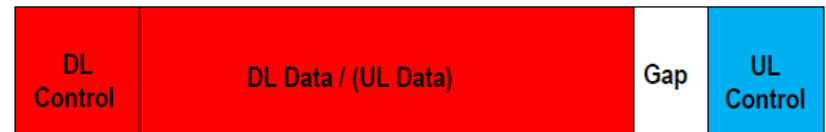
- NR utilizes **scalable numerology** (subcarrier spacings, CP length) and **flexible slot (mini-slot) structure** optimized for various services including URLLC in time & frequency domain

**Subcarrier Spacing:**  $f_0 * 2^m$  with  $f_0 = 15$  kHz and scaling factor is  $2^m$  with  $m \{-2, 0, 1, \dots, 5\}$

m =	-2	0	1	2	3	4	5	...
Subcarrier Spacing [kHz]	3.75	15	30	60	120	240	480	...
Symbol Length [ $\mu$ s]	266.67	66.67	33.33	16.67	8.333	4.17	2.08	...



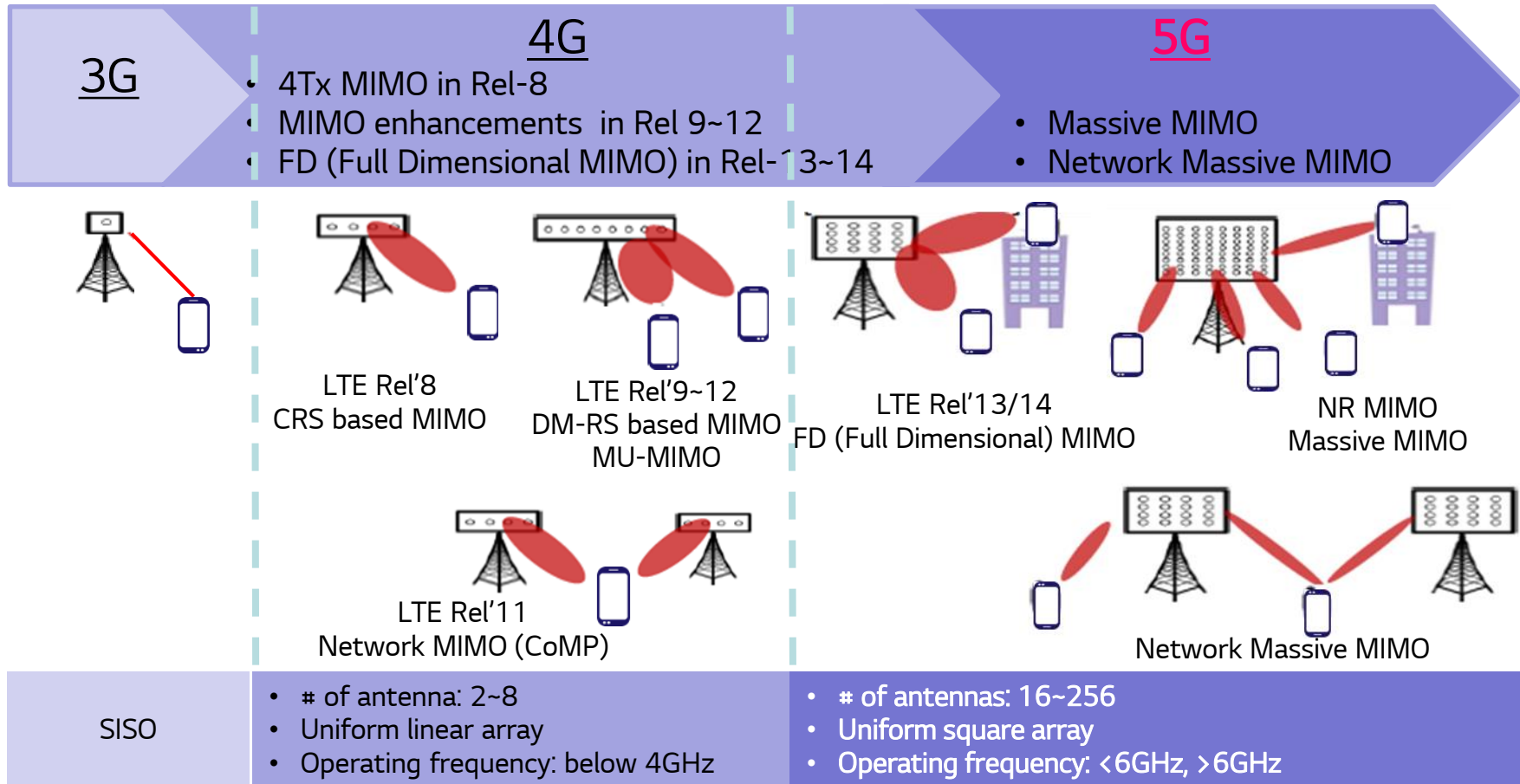
Slot & Mini slot (scalable slot length)



DL-UL Flexible Slot Configuration

# NR MIMO [1/2]

- 기지국 혹은 단말에 장착된 수십 개 이상의 안테나를 이용하여, 다중 스트림 송수신을 통한 전송 속도 향상, 빔포밍을 통한 커버리지 향상, 다중 사용자 동시 송수신을 통한 시스템 용량 향상



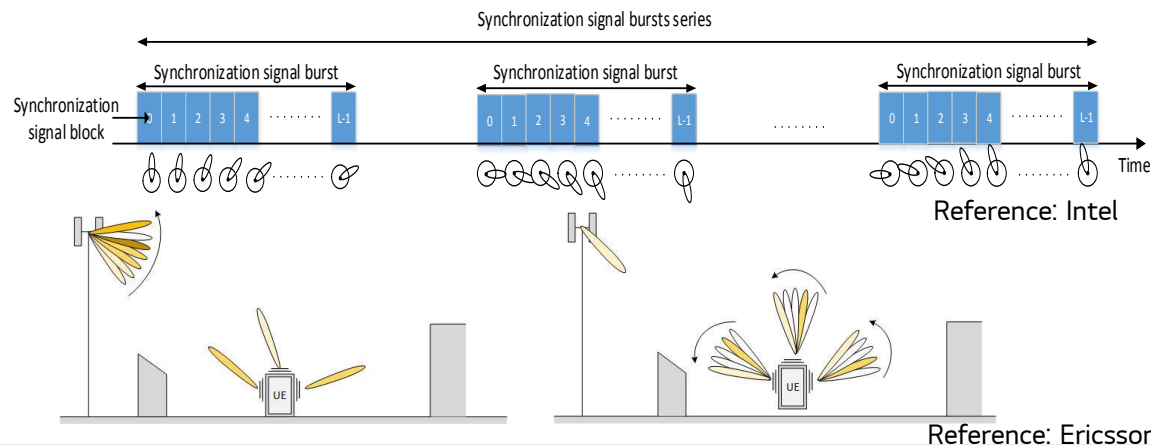
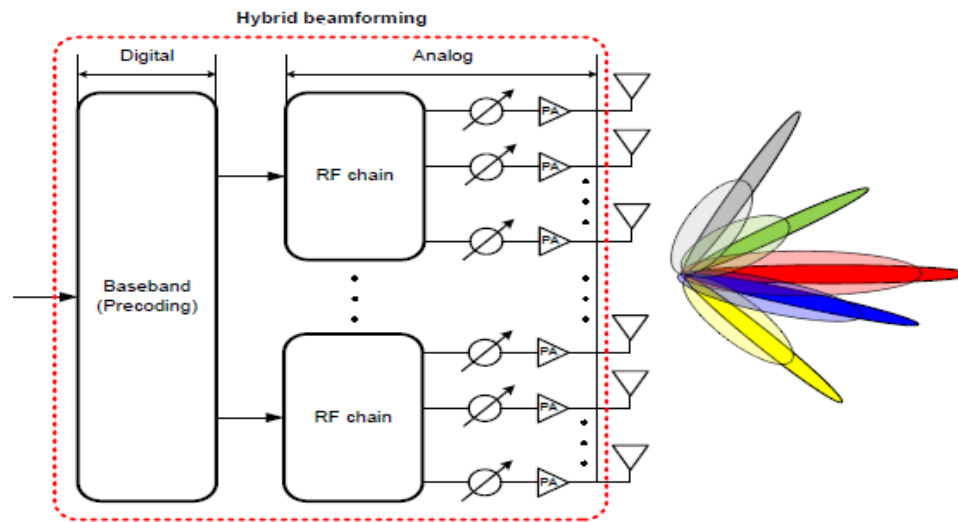
## Massive MIMO at Higher Carrier Frequencies (>> 6GHz)

### • Hybrid Beamforming

- ✓ Analog beamforming + Digital beamforming
- ✓ Beneficial in terms of hardware implementation complexity and power consumption

### • Beam based air interface

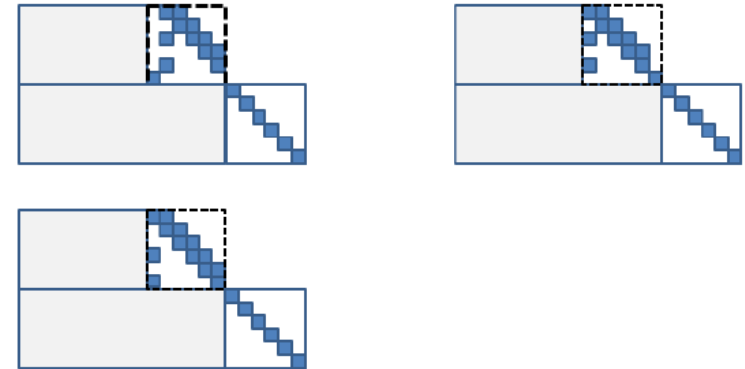
- ✓ Single sector-wide beam may not be enough to provide sufficient coverage
- ✓ All channels are beam formed in NR mmWave



20Gbps급의 초고속 전송 데이터를 낮은 복잡도로 처리할 수 있는 채널 오류 정정 부호 및 고신뢰도 전송을 위해 매우 낮은 전송 오류율을 달성하는 있는 채널 오류 정정부호 필요

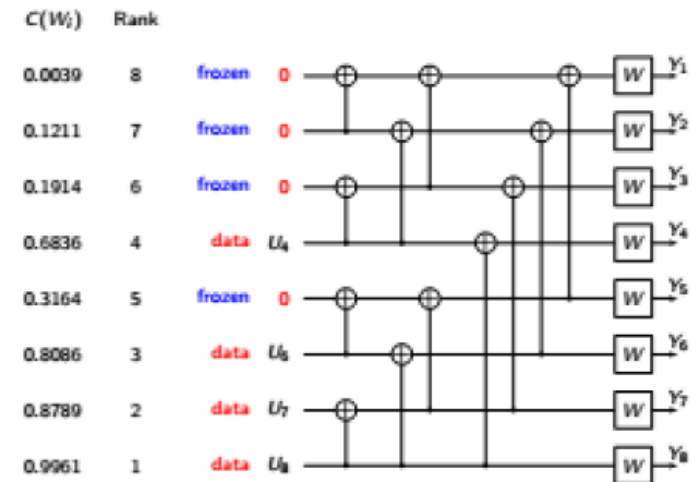
## LDPC Coding

- 데이터 decoding시 area efficiency 및 소모 전력 측면에서 3G/4G의 turbo coding보다 우수
  - ✓ 다소의 성능 이득 및 낮은 error floor 달성도 가능
- eMBB용 데이터 채널에 대해 Quasi-Cyclic LDPC code 채택



## Polar Coding

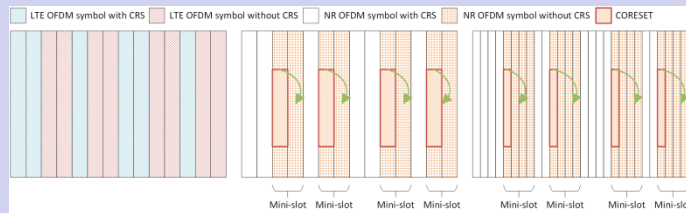
- 상대적으로 작은 정보 비트 길이를 가지는 제어 채널에 대해 전송 오류율을 최소화시키기 위한 코딩 기법
  - ✓ TBCC에 비해 다소의 성능 이득 및 낮은 error floor 달성도 가능
- List decoding의 list 크기를 증가시키면 성능 향상 (decoding 복잡도 증가)



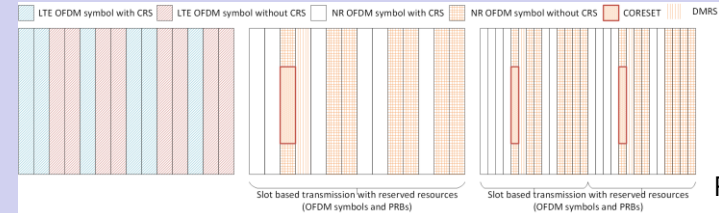
## Downlink Sharing

- NR-LTE coexistence in overlapping spectrum

- ✓ NR supports DL transmissions scheduled in LTE DL non-MBSFN subframes with RE level rate matching around CRS symbols
- ✓ Slot / mini-slots can be scheduled on OFDM symbols not carrying CRS



Mini-slot level scheduling (only an example)

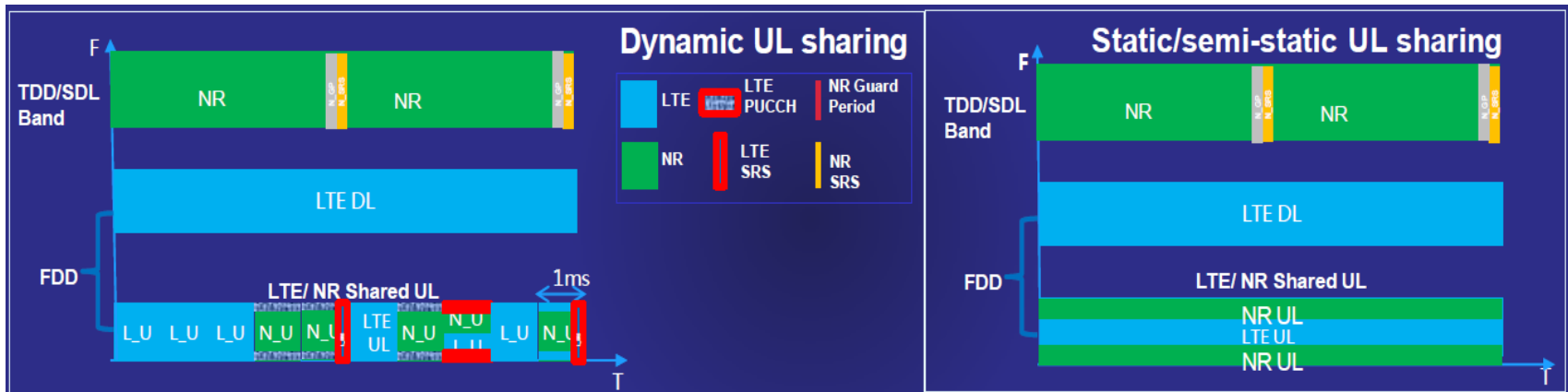


Slot level scheduling (only an example)

Reference: AT&T

## Uplink Sharing

- UL resource in LTE spectrum sharing only from network perspective
- UL resource in LTE spectrum sharing from UE perspective



Reference: Huawei

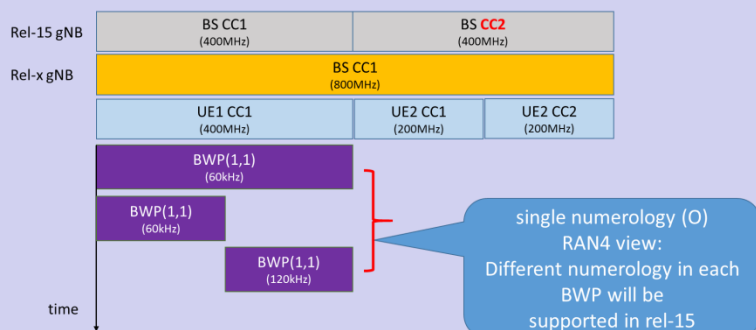
## Carrier Aggregation

- From RAN1 specification perspective, the max # of NR carriers for CA and DC is 16
- Following combinations are now being specified by RAN4 WG

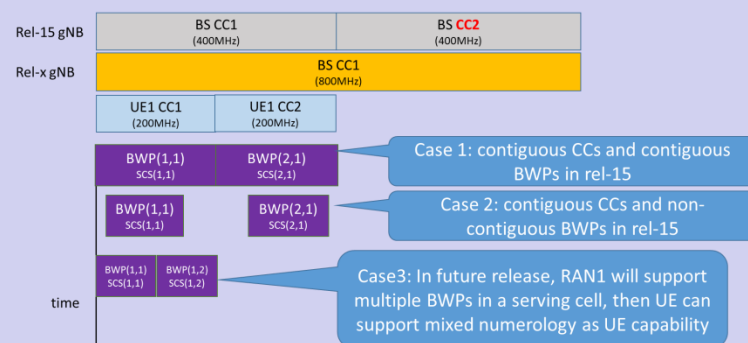
• New DC band combination of LTE 1CC + NR 1CC
• New DC band combination of LTE 2DL/1UL + one NR band
• New DC band combination of LTE 3DL/1UL + one NR band
• New DC band combination of LTE 4DL/1UL + one NR band
• New DC band combination of LTE 5DL/1UL + one NR band
• Dual connectivity (DC) band combinations of LTE xDL/1UL (x=1, 2, 3, 4) + Inter-band NR 2DL/1UL NR WI
• Intra-band NR CA (mDL/1UL) and inter-band NR CA (nDL/1UL) (m and n are FFS)

## Carrier Bandwidth Part

- For UE, up to 4 bandwidth part configurations for each serving cell
- For UE, one active bandwidth part for each serving cell in Rel-15



Single CC case



Multiple CC case

- **Standardization for 5G NR in 3GPP**
  - **NR is new radio for 5G**
  - **Phased approach for NR standardization**
    - Phase 1 work item is underway
    - **Stage 3 completion of NR NSA work has been completed** and version 15.0.0 of NR specification has been published
    - Phase 2 study items will start in Q1 2018 in parallel with phase 1 work item for SA
  
- **Standardization for LTE-A Pro in 3GPP**
  - **LTE-A Pro continues to evolve for 5G**
  - **LTE-A Pro Rel-15/16 will meet key IMT-2020 requirements** while providing backward compatibility
  
- **Both NR & LTE-A Pro are essential ingredients for 5G operation & system**
  - IMT-2020 submission will include both NR & LTE-A Pro specifications
  - Tight interworking between NR & LTE-A Pro is quite important, especially in the initial roll-out phase of 5G
    - Non Standalone operation for NR anchored on eLTE (DC operation)
    - E-UTRA connected to 5G-CN
    - LTE-NR coexistence