NOKIA

5G New Radio Design

Expanding the human possibilities of technology to make our lives better

Fall VTC-2017, Panel

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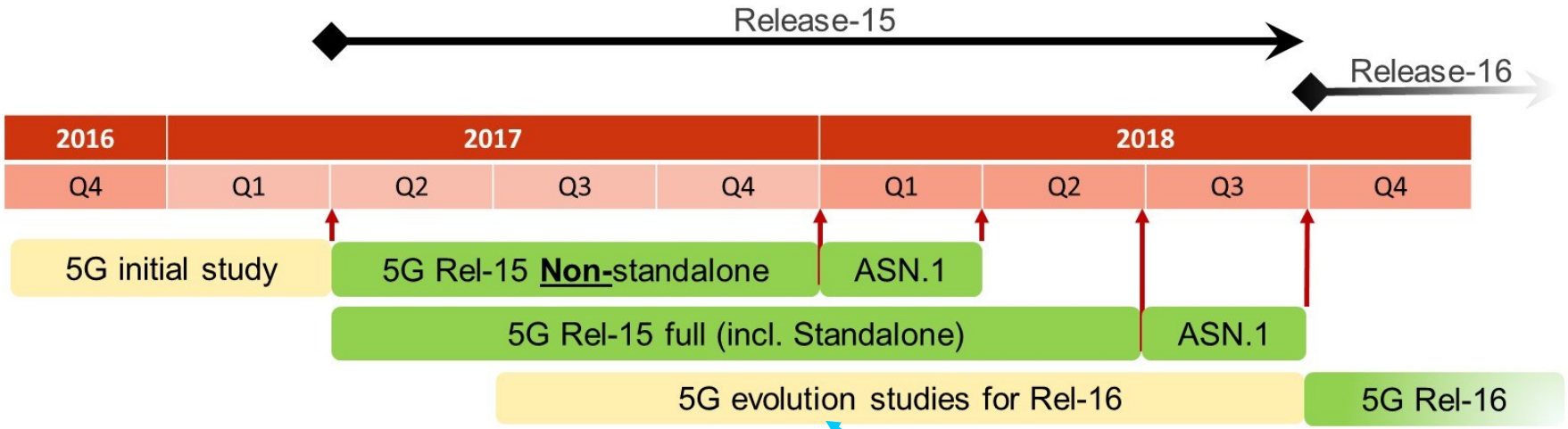
3GPP New Radio

3GPP 5G NR agreed timeline: No changes since last time



- 5G NR timeline was kept unchanged
- RAN#77 (Sept.2017) agreed further feature prioritization for RAN1, RAN2 and RAN4 specfication work to keep the very challenging 5G NR time line

Release 16 study items on hold until Dec. 2017 to prioritize Release 15 5G NR work item → technical work to start 1Q2018

3GPP Release 15 work and study items: What else from January onwards?

Rel-15 Work item

New Radio Access Technology

Studies on-going

- Separation of CP and UP for split option 2
- CU-DU lower layer split for New Radio
- Test methods for New Radio
- Self-evaluation towards IMT-2020 submission

Studies toward Rel-16 on hold until Dec. 2017

- Non-orthogonal multiple access
- Non-terrestrial networks*
- EV2V evaluation methodology
- Integrated Access Backhaul
- Unlicensed spectrum

Additional New Work Items and Studies targeting for Rel-16 are still expected to be approved in December 2017 3GPP RAN plenary

- RAN level discussion on scenario etc. Ongoing

Physical Channels & Physical Signals

PDSCH
DL shared channel

PBCH
Broadcast channel

PDCCH
DL control channel

GNodeB

PUSCH
UL shared channel

PUCCH
UL control channel

PRACH
Random access channel

User Equipment

DL Physical Signals
Demodulation Ref (DMRS)
Phase-tracking Ref (PT-RS)
Ch State Inf Ref (CSI-RS)
Primary Sync (PSS)
Secondary Sync (SSS)

UL Physical Signals
Demodulation Ref (DMRS)
Phase-tracking Ref (PTRS)
Sounding Ref (SRS)

5G NR Numerology : Overview

Numerologies with normal CP (subframe = 1msec)

	Slot Configuration 0					
Subcarrier spacing [kHz]	15	30	60	120	240*	480**
Symbol duration [us]	66.7	33.3	16.6	8.33	4.17	2.08
Nominal CP [us]	4.7	2.41	1.205	0.60	0.30	0.15
Nominal max BW [MHz]	49.5	99	198	396	397.4	397.4
Max FFT size	4096	4096	4096	4096	2048	1024
Min scheduling interval (symbols)	14	14	14	14	14	14
Min scheduling interval (slots)	1	1	1	1	1	1
Min scheduling interval (ms)	1.0	0.5	0.25	0.125	0.0625	0.0312

*SS Block only

**Not supported

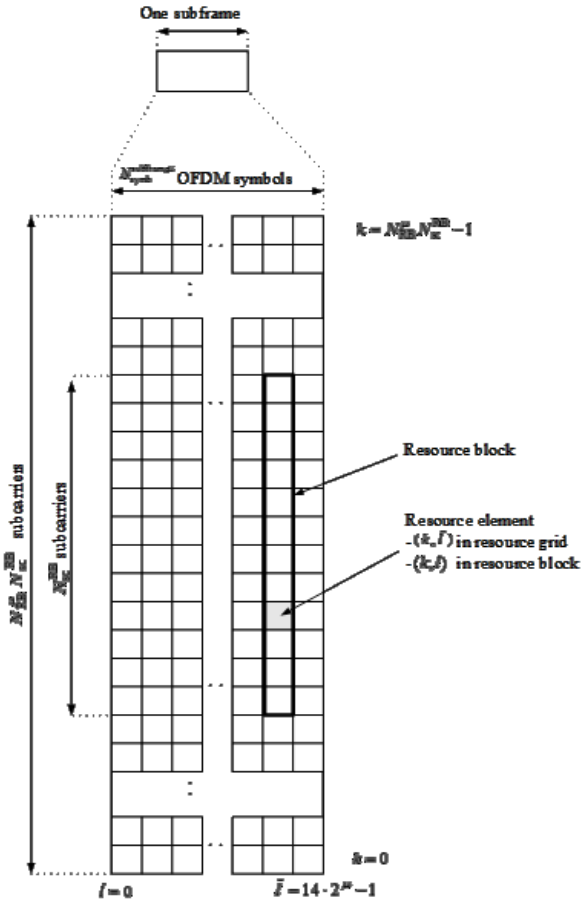
Numerologies with extended CP (subframe = 1msec)

Subcarrier spacing [kHz]	Symbol Duration[us]	Ext CP[us]	Nom max BW	FFT Size	Sched Interval (sym)	Sched Interval (slot)	Sched Interval (ms)
60	16.6	4.2	198	4096	12	1	0.25

Frame Structure (120 KHz SC) & Modulation

- 80 slots/10 ms frame
- 14 OFDM symbols/slot
- 24-275 PRBs/slot
- 12 subcarriers/PRB
- Occupied BW
  - Minm = 24x12x120 = 34.56 MHz
  - Maxm = 275x12x120 = 396 MHz

Modulation scheme	UL /DL
π/2-BPSK	UL only, In combination with transform precoding only
QPSK	UL/DL
16QAM	UL/DL
64QAM	UL/DL
256QAM	UL/DL



Downlink Channels & Signals

PDSCH and PDCCH

	PDSCH (5G)	PDSCH (LTE)	PDCCH (5G)	PDCCH (LTE)
Purpose	Transmit DL Data	Transmit DL Data	Transmit DL Control	Transmit DL Control
Waveform	OFDM	OFDM	OFDM	OFDM
Bandwidth	Numerology Dependent	Max: 1.4 / 3 / 5 / 10 / 15 / 20 MHz	Flexible, Numerology Dependent	Fixed: 1.4 / 3 / 5 / 10 / 15 / 20 MHz
Reference signals	UE-specific	Cell specific or UE-specific (Release 10)		
Phase noise compensation	Yes	No		
Modulation	Up to 256QAM	Up to 256QAM	QPSK	QPSK
Coding scheme	LDPC	Turbo	Polar	TBCC

Uplink Channels & Signals

PUSCH – Uplink shared channel

	PUSCH (5G)	PUSCH (LTE)
Purpose	Used to transmit uplink data and control information	Used to transmit uplink data and control information
Waveform	OFDM/SC-FDMA (Optional)	SC-FDMA
Bandwidth	See numerology	Max: 1.4 / 3 / 5 / 10 / 15 / 20 MHz
Phase noise compensation	Yes	No
Modulation	Up to 256 QAM & $\pi/2$–BPSK	Up to 64QAM
Coding scheme	LDPC	Turbo


Massive MIMO

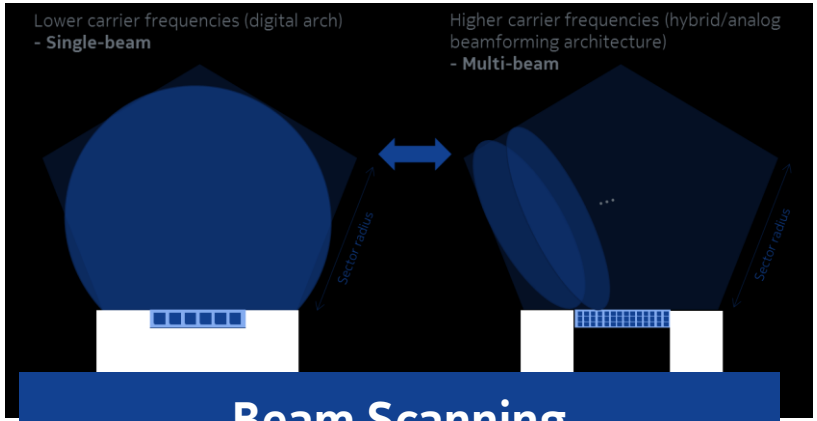
MIMO in 3GPP

Release 8	Release 9	Release 10	Release 11
• 4x4MIMO • 4x2MIMO • 8RX uplink • Uplink CRAN	• 8TX TM8	• 8TX TM9	• Downlink CoMP (TM10)

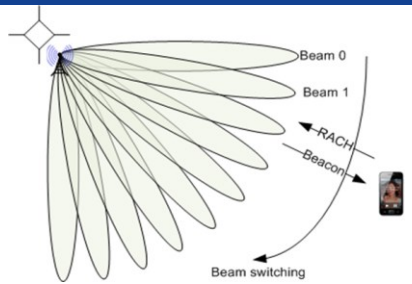
Release 12	Release 13	Release 14	Release 15+
• Downlink eCoMP • New 4TX codebook	• Massive MIMO 16TX	• Massive MIMO 32TX	• 5G massive MIMO 64TX+

Massive MIMO in 3GPP New Radio – Beam Based Air Interface

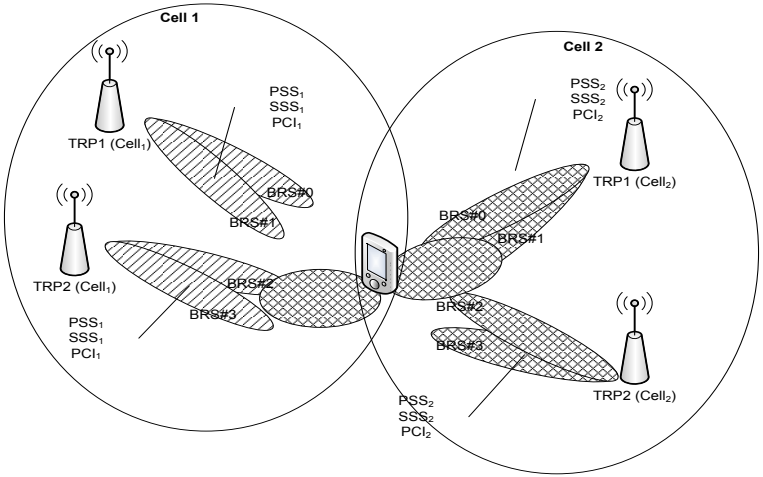
Beamformed Control Channels



Beam Scanning



Beam Management



- Acquisition and maintenance of a set of beams for TX and RX at base and UE
- CoMP is built in

Beam Management and CSI

Downlink Codebook Overview

Type I Codebooks:

- Standard resolution CSI feedback
- Single panel and multi-panel

Type II Codebooks:

- High resolution CSI feedback targeting MU-MIMO
- Non-precoded and precoded CSI-RS

Designed for cross-polar antennas

Supported Antenna Ports

Ports	Type I		Type II	
	Single Panel	Multi-Panel	Non-precoded CSI-RS	Precoded CSI-RS
2	✓			
4	✓		✓	✓
8	✓	✓	✓	✓
12	✓		✓	✓
16	✓	✓	✓	✓
32	✓	✓	✓	✓

CSI Feedback

DL Codebook Overhead Example

Type I		Type II			
Single Panel	Multi-Panel	Non-precoded		Precoded	
L=2: 9/1	Mode 1: 10/1	L=2:	31/12-24	L=2:	25/12-24
L=4: 7/3	Mode 2: 10/3	L=4:	59/28-48	L=4:	51/28-48

M/N indicates M wideband bits and N bits per subband (Type II entries indicate the range of possible bits per SB)

- L – Number of beams configured in the codebook
- 16 ports, 2 layers assumed
  - Single panel and non-precoded: N_1=4, N_2=2
  - Multi-panel: 2 panels, N_1=2, N_2=2
  - Precoded: Selection sampling factor (d) = 1


sub6GHz NR Performance

5G vs. 4G Capacity per Cell at 2GHz – 16x4 MIMO

LTE
2GHz
750m ISD
16x4
eNB=(1,8,2)

2GHz	20MHz	5.12 bps/Hz	102 Mbps cell throughput

1.5 x

2GHz	20MHz	7.73 bps/Hz *	155 Mbps cell throughput

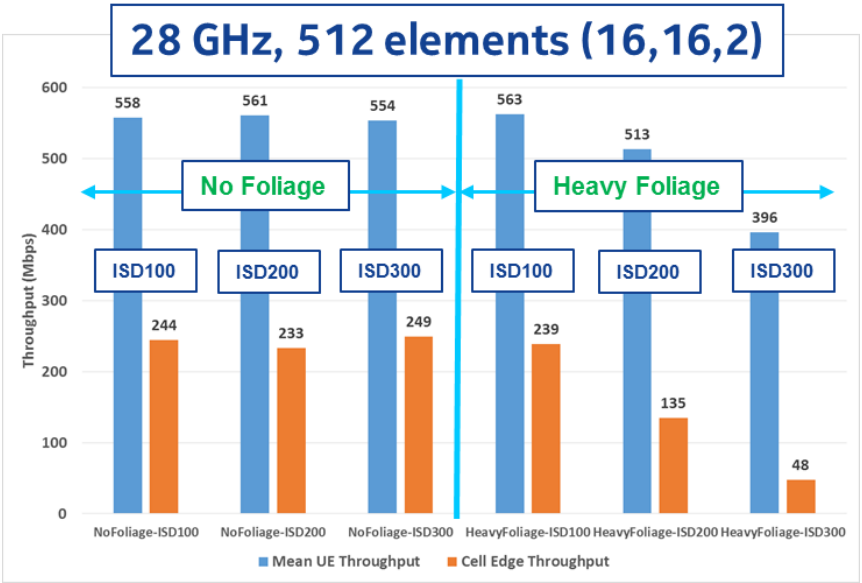
NR
2GHz
750m ISD
16x4
gNB = (1,8,2)

- **In Full Buffer, NR Codebooks show significant gains over LTE Codebooks**
  - **Mean UE throughput: 26%**
  - **Cell edge: 25%**

* Includes 20% improvement due to lean carrier in NR


mmWave Performance

Early 5G use case: Extreme broadband to the home (mmWave)



Tasks Ahead?

- Prioritization of essential functionalities for NSA completion
- Self Evaluation for IMT-2020 Submission
- NR numerologies for sub 6GHz & mmWave
- Channel bandwidths for various NR bands ?
- Massive MIMO : Type of Codebooks supported?
- UE capabilities
- mmWave : IAB/Deployments, ESA