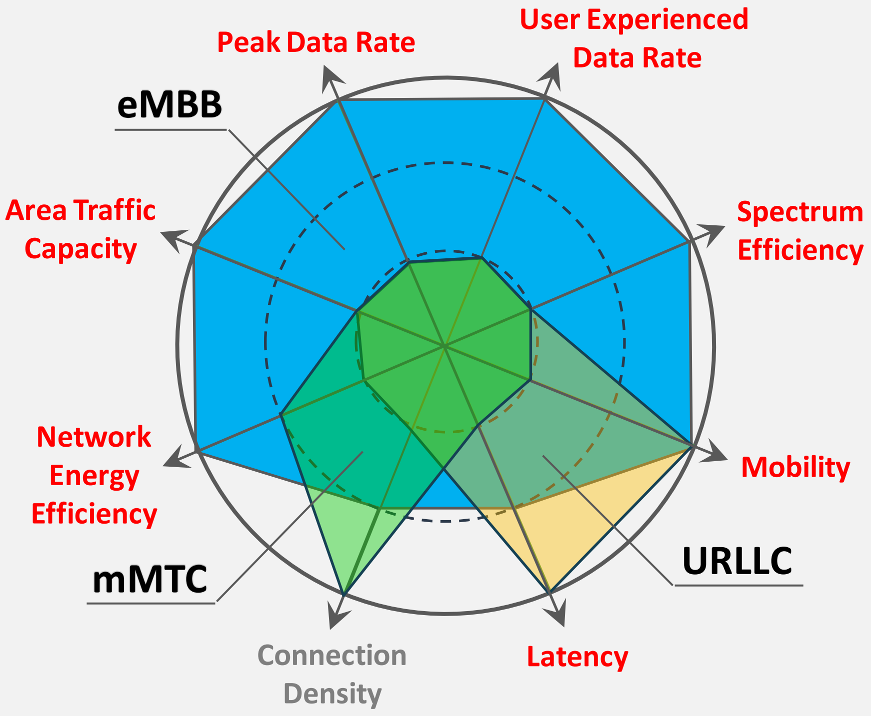
Self evaluation:

Enhanced Mobile Broadband (eMBB) Evaluation results

Workshop on 3GPP submission towards IMT-2020
(October 24-25, 2018)

WU Yong
wuyong@huawei.com

Enhanced mobile broadband in IMT-2020



IMT-2020 Key capabilities

Technical performance requirement
Peak data rate New
Peak spectral efficiency
User experienced data rate New
5th percentile user spectral efficiency
Average spectral efficiency
Area traffic capacity New
Energy efficiency New
Mobility
User plane latency
Control plane latency
Mobility interruption time

IMT-2020 requests significantly extended eMBB capability

eMBB requirement overview

Technical performance requirement	DL	UL	Comparison to IMT-Advanced requirement
Peak data rate	20 Gbit/s	10 Gbit/s	***~6x LTE-A (Rel-10)***
Peak spectral efficiency	30 bit/s/Hz	15 bit/s/Hz	***2x IMT-Advanced***
User experienced data rate (5th percentile user data rate)	100 Mbit/s	50 Mbit/s	-
5th percentile user spectral efficiency	~3x IMT-Advanced	~3x IMT-Advanced	***~3x IMT-Advanced***
Average spectral efficiency	~3x IMT-Advanced	~3x IMT-Advanced	***~3x IMT-Advanced***
Area traffic capacity	10 Mbit/s/m^2	-	-
Energy efficiency	High sleep ratio and long sleep duration under low load		-
Mobility class With traffic channel link data rates	-	Up to 500km/h, with 0.45 bit/s/Hz	***1.4x mobility class; 1.8x mobility link data rate***
User plane latency	4ms	4ms	***>2x reduction compared to IMT-Advanced***
Control plane latency	20ms	20ms	***>5x reduction compared to IMT-Advanced***
Mobility interruption time	0	0	***Much reduced***

IMT-2020 requests significantly enhanced eMBB capability

eMBB evaluation overview

Technical performance requirement	Evaluation method	Test environment		
		Indoor Hotspot	Dense Urban	Rural
Peak data rate	Analysis	NR, LTE		
Peak spectral efficiency	Analysis	NR, LTE		
User experienced data rate (5th percentile user data rate)	Analysis, or *SLS*		NR	
5th percentile user spectral efficiency	*SLS*	NR	NR	NR, LTE
Average spectral efficiency	*SLS*	NR	NR	NR, LTE
Area traffic capacity	Analysis	NR		
Energy efficiency	Inspection	NR, LTE		
Mobility class With traffic channel link data rates	*SLS* + *LLS*	NR	NR	NR, LTE
User plane latency	Analysis	NR, LTE		
Control plane latency	Analysis	NR, LTE		
Mobility interruption time	Analysis	NR, LTE		
RIT evaluation summary		**Rel-15 NR**	**Rel-15 NR**	**Rel-15 NR, LTE**

3GPP 5G technology for eMBB

Frame structure

- NR supports *reduced guard band ratio* with large CC bandwidth

SCS	Guard band ratio	
15kHz	10MHz BW: 6.4%	40 MHz BW: 2.8%
30kHz	20 MHz BW: 8.2%	100 MHz BW: 1.7%
60kHz	40 MHz BW: 8.2%	100 MHz BW: 2.8%

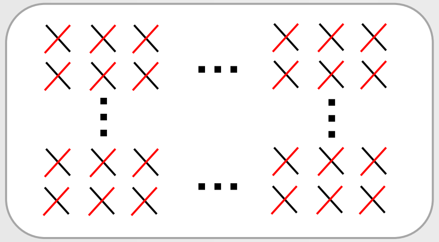
- NR Multiple SCSs enable reduced slot durations

SCS (kHz)	Slot duration	SCS (kHz)	Slot duration
15	1ms	60	0.25ms
30	0.5ms	120	0.125ms

- NR PDCCH and PDSCH sharing allows overhead reduction, especially in large CC bandwidth

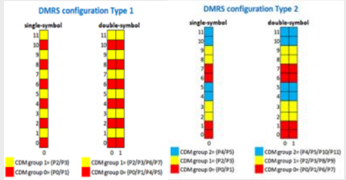
Massive MIMO

- NR and LTE support up to 32 gNB ports codebook for FDD; and larger than 64 gNB ports for TDD



- **NR Type I/II codebook**
- **LTE codebook**

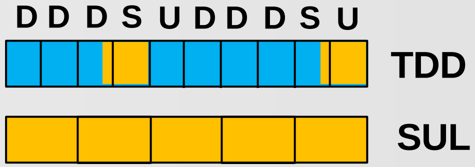
- NR supports 12 orthogonal DM-RS ports for MU pairing. LTE supports 4 orthogonal UE specific RS ports

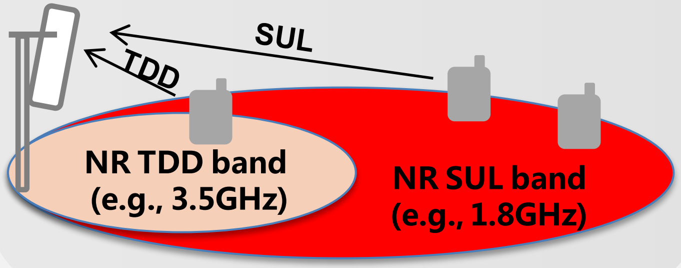


- NR overhead reduction for reference signals (RS): DMRS overhead reduction for DL/UL compared to LTE-A; no CRS.

Flexible spectrum utilization

- NR supports up to 16 CC aggregation. Max BW of each CC is 100 MHz (FR1) or 400 MHz (FR2).
- LTE supports up to 32 CC aggregation. Max BW of each CC is 20 MHz.
- NR supports operating on a TDD band with supplementary uplink (SUL) band





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Self evaluation report TR 37.910


3GPP TR 37.910 V1.0.0 (2018-09)

Technical Report

3rd Generation Partnership Project;
Technical Specification Group Radio Access Network;
Study on Self Evaluation towards IMT-2020 Submission
(Release 15)

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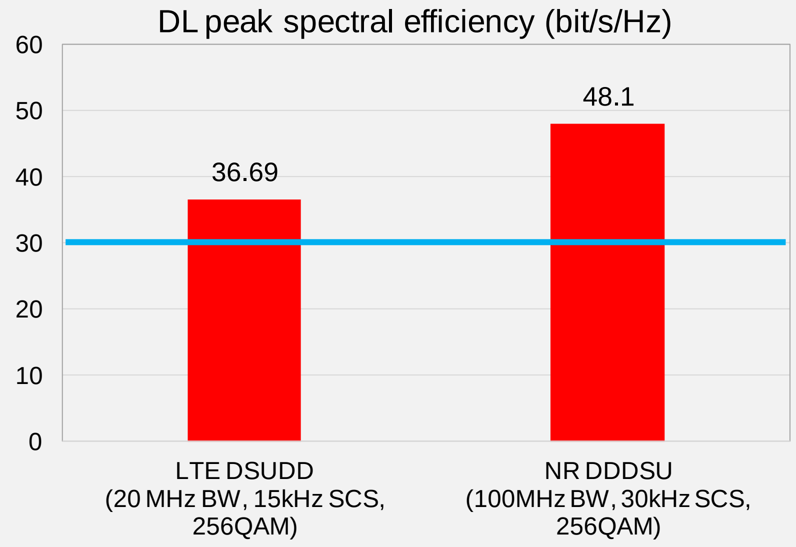
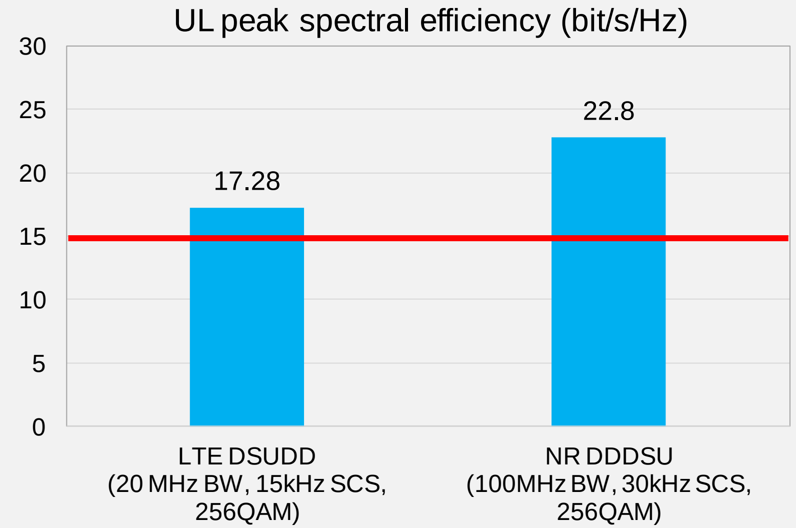
- TR 37.910 v1.0.0 provides the preliminary assessment of 3GPP 5G towards IMT-2020 requirements

- **See Section 5 for the detailed evaluation against eMBB requirements.**

Preliminary evaluation on
Peak data rate and spectral efficiency

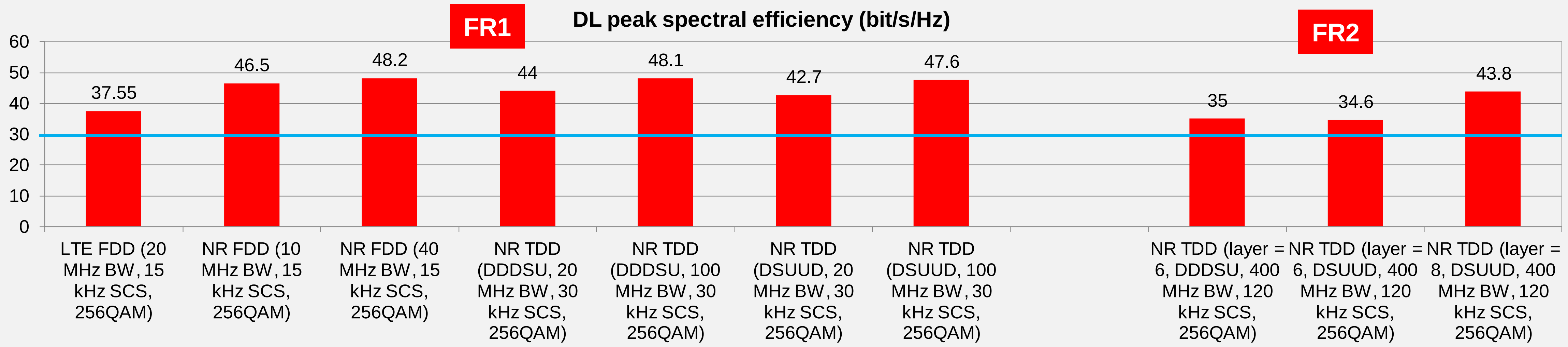
- **Peak spectral efficiency:**
  - DL: 8 layer for FR1; 6 layer for FR2; 256QAM (NR, LTE) / 1024QAM (LTE), max code rate = 0.9258 (NR) / 0.93 (LTE)
  - UL: 4 layer, 256QAM, max code rate = 0.9258 (NR) / 0.93 (LTE)
- **Contributing technical components:**
  - NR large CC bandwidth introduces reduced guard band ratio
  - NR small overhead for DL:
    - ✓ For PDCCH, as low as 0.6%@100 MHz for low load; 8-layer DMRS overhead reduced to 9.5%; no CRS
  - NR small overhead for UL:
    - ✓ 4-layer DMRS overhead reduced to 7% under UL OFDMA; "Special subframe" can be used to transmit UL data -> Overhead reduced.
  - ... ...

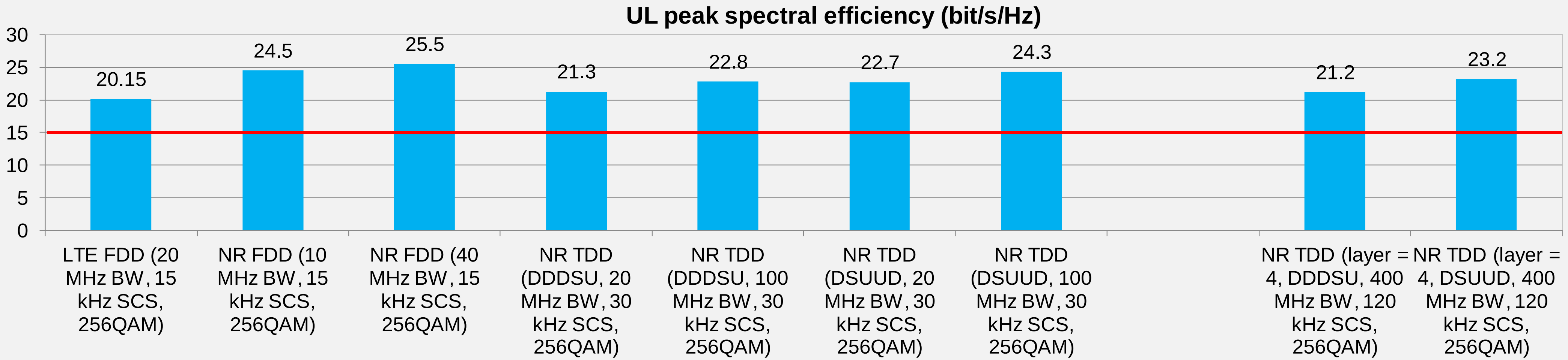




Preliminary evaluation on
Peak data rate and spectral efficiency

- **Various NR/LTE configurations are evaluated; see Section 5.1 of TR37.910 for details.**





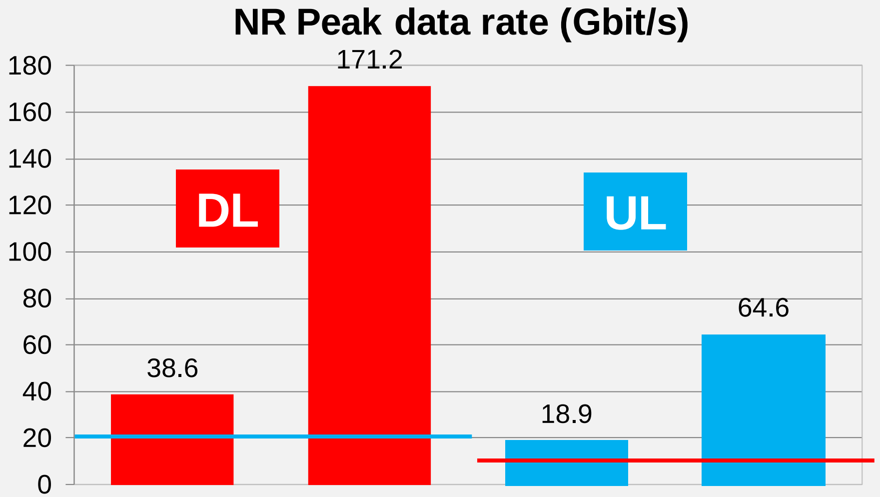
Preliminary evaluation on

Peak data rate and spectral efficiency

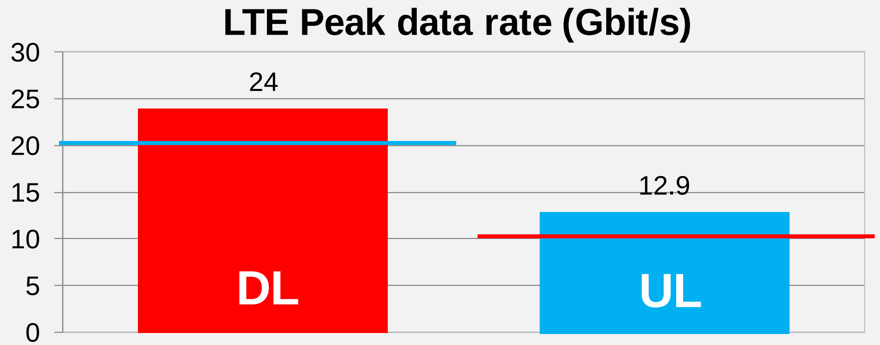
- **Peak data rate:**

Peak data rate =
(Peak SE) x (Aggregated bandwidth)

- NR Max aggregated bandwidth :
  - ✓ **FR1 (15 kHz SCS):** 16 CC x 50 MHz/CC = ***800 MHz***
  - ✓ **FR1 (30/60 kHz SCS):** 16 CC x 100 MHz/CC = ***1.6 GHz***
  - ✓ **FR2 (120 kHz SCS):** 16 CC x 400 MHz/CC = ***6.4 GHz***
- LTE Max aggregated bandwidth:
  - ✓ 32 CC x 20 MHz/CC = ***640 MHz***



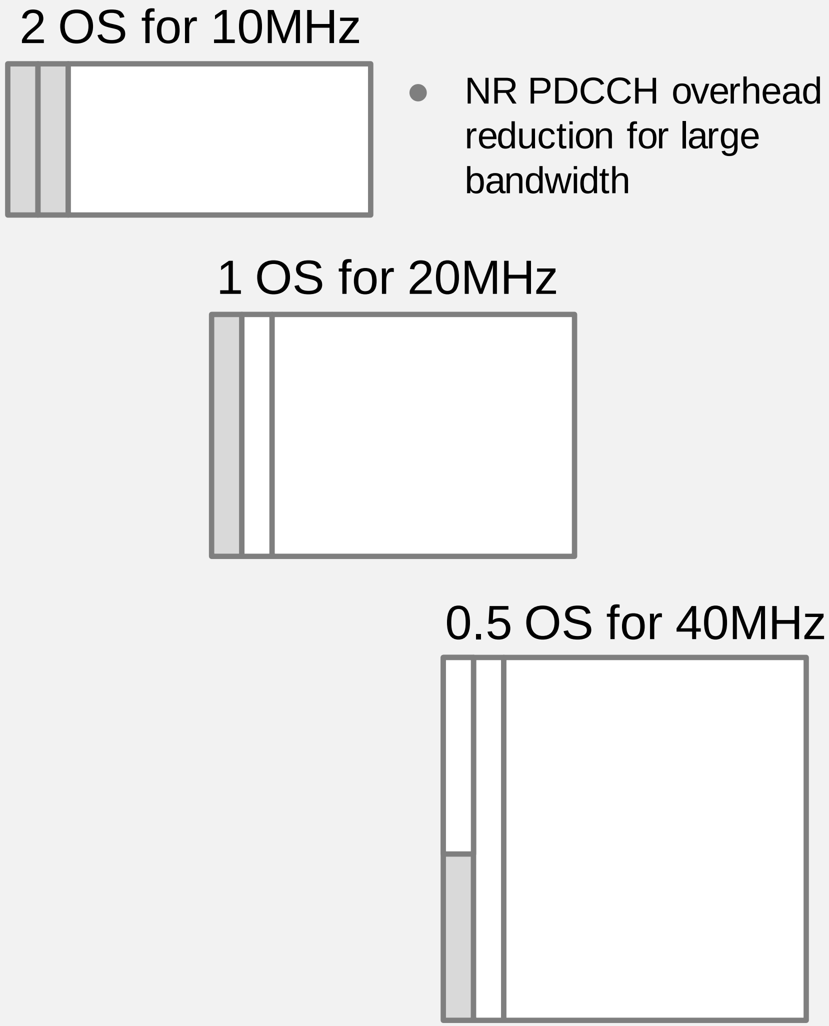
- For various NR configurations



- For LTE FDD (256QAM) with 640 MHz BW

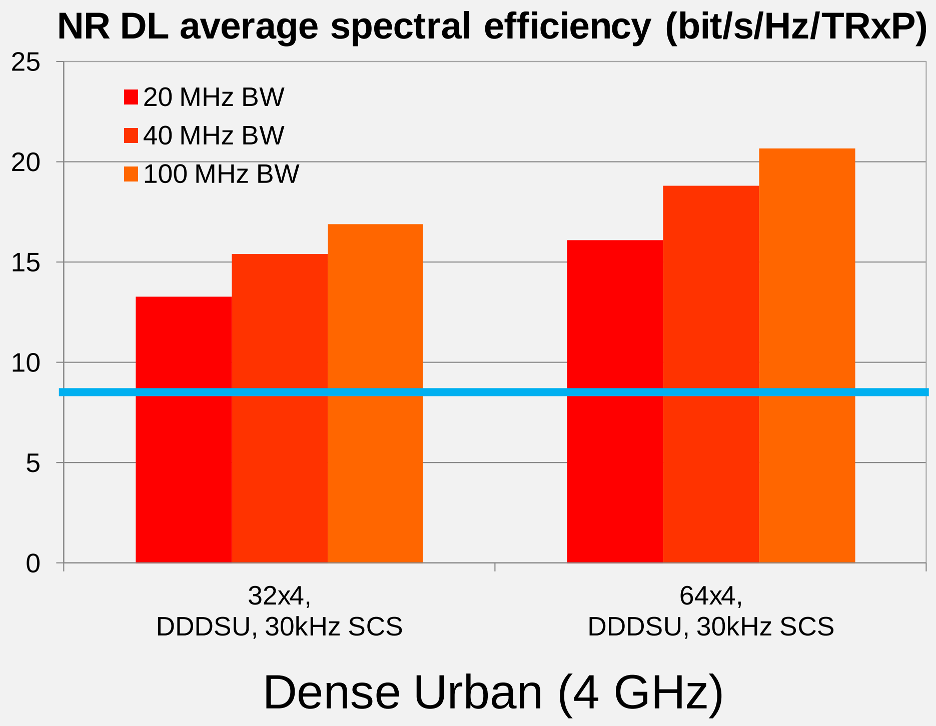
Preliminary evaluation on Average and 5th percentile user SE

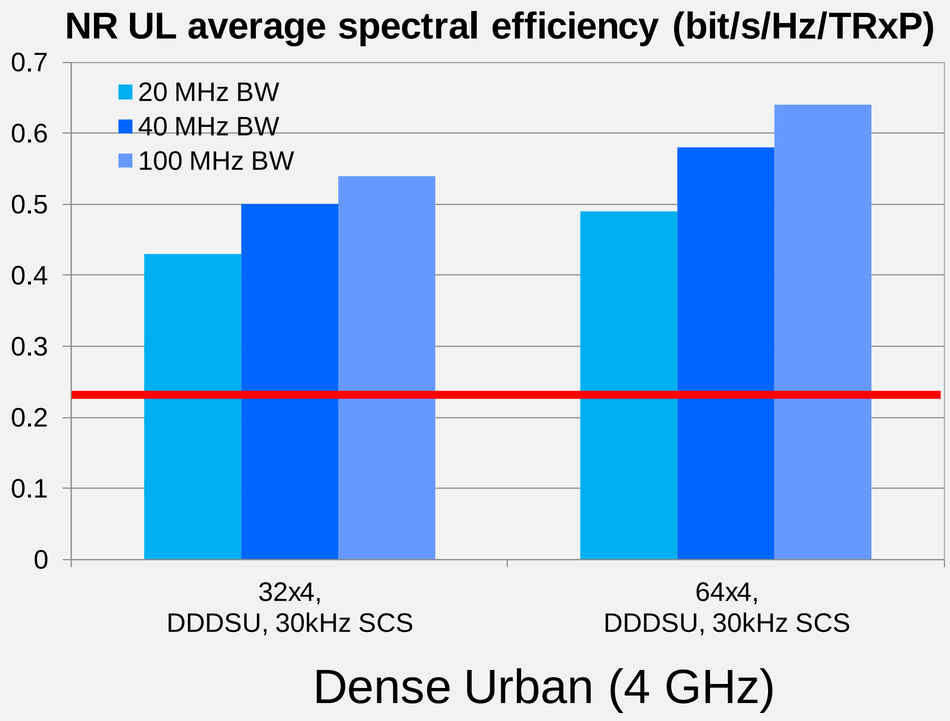
- **Contributing technical components for DL:**
  - *NR frame structure:*
    - ✓ NR large CC bandwidth introduces reduced guard band ratio
    - ✓ NR PDCCH and PDSCH sharing allows overhead reduction, especially in large CC bandwidth
  - *NR Massive MIMO:*
    - ✓ NR Type II codebook and 12 orthogonal DMRS enhances MU-MIMO spectral efficiency especially for FDD
    - ✓ NR fast CSI feedback and SRS capacity enhancement improves MU-MIMO spectral efficiency especially for TDD.
  - … …
- **Contributing technical components for UL:**
  - NR large CC bandwidth introduces reduced guard band ratio
  - NR DMRS overhead reduction for UL OFDMA compared to LTE-A
  - NR SRS capacity enhancement accelerates UL CSI derivation
  - NR OFDMA enables flexible and efficient resource allocation
  - … …



Preliminary evaluation on Average and 5th percentile user SE

- **Preliminary NR evaluation results for Dense Urban:**
  - *Larger CC bandwidth brings improved SE (~30%) due to guard band ratio reduction and PDCCH overhead reduction*
  - *NR Massive MIMO: 64 TXRU brings additional gain over 32 TXRU in TDD.*

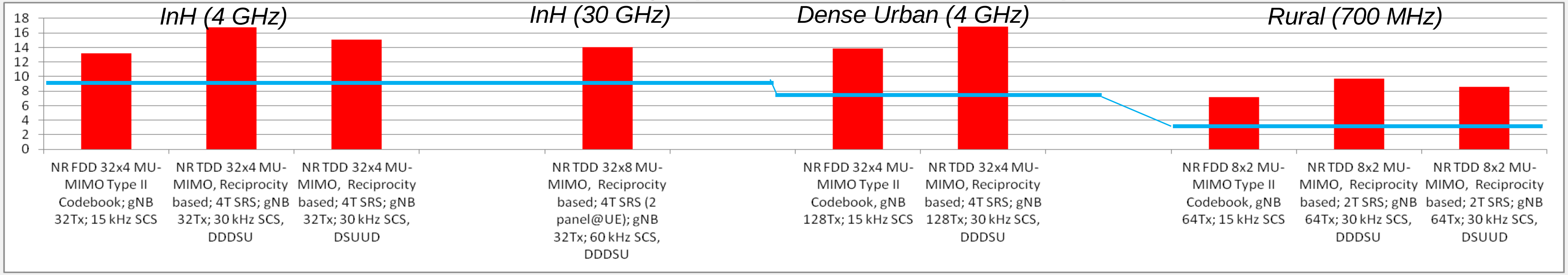




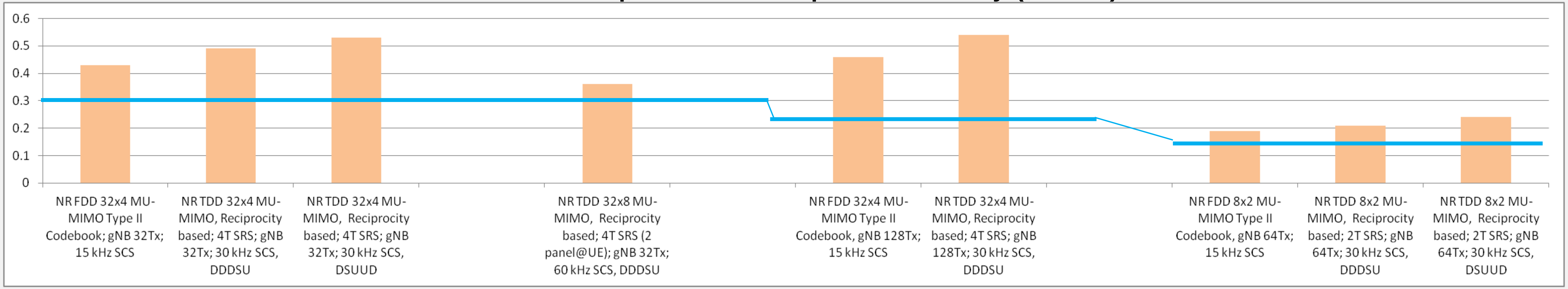
Preliminary evaluation on Average and 5th percentile user SE

- Various NR configurations are evaluated. See Section 5.4 of TR37.910 for details

NR DL average spectral efficiency (bit/s/Hz/TRxP)



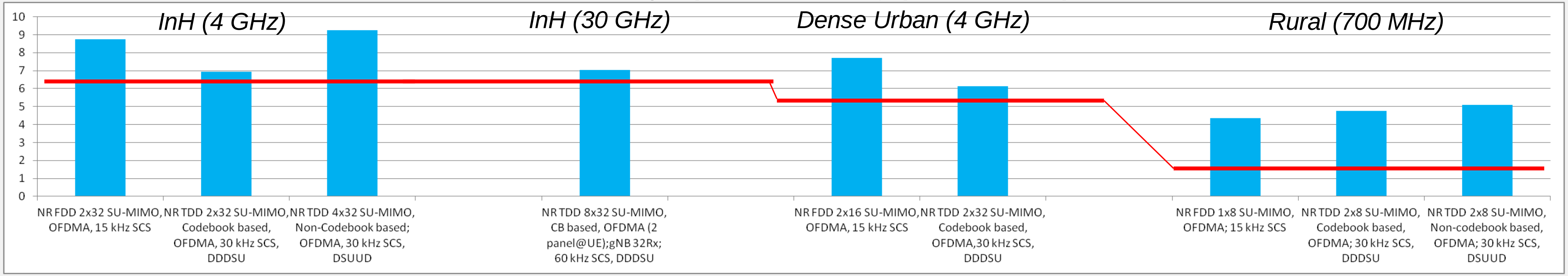
NR DL 5th percentile user spectral efficiency (bit/s/Hz)



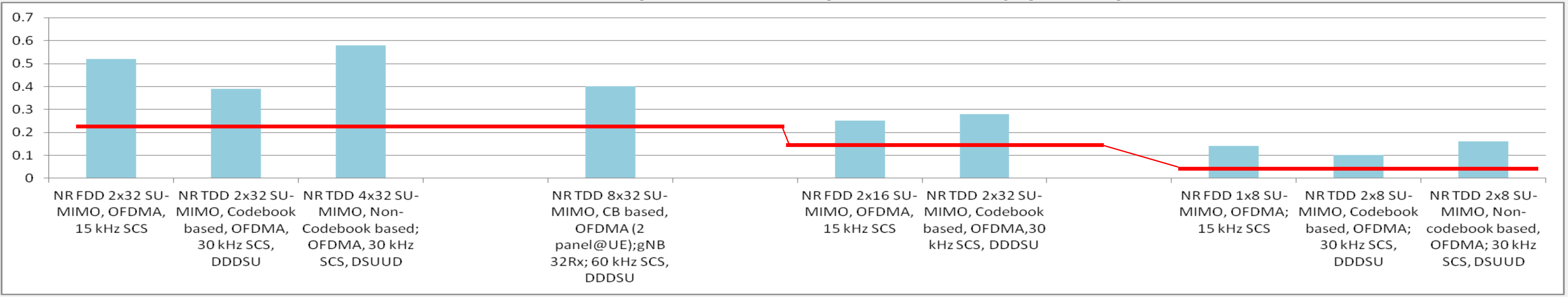
Preliminary evaluation on Average and 5th percentile user SE

- Various NR configurations are evaluated. See Section 5.4 of TR37.910 for details

NR UL average spectral efficiency (bit/s/Hz/TRxP)



NR UL 5th percentile user spectral efficiency (bit/s/Hz)

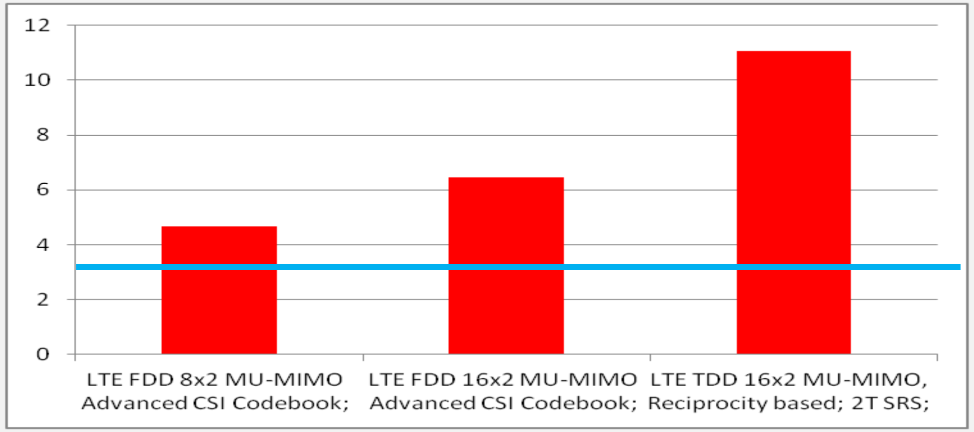


Preliminary evaluation on
Average and 5th percentile user SE

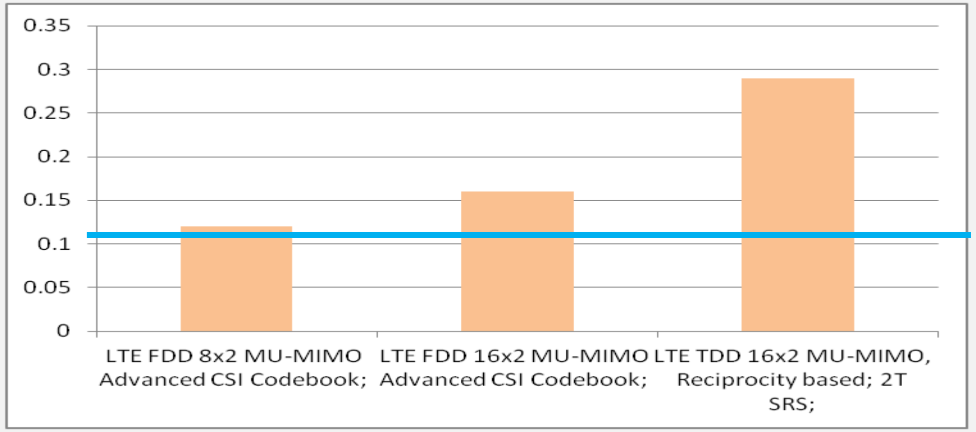
- Various LTE configurations are evaluated for Rural. See Section 5.4 of TR37.910 for details

DL

LTE DL average spectral efficiency (bit/s/Hz/TRxP)

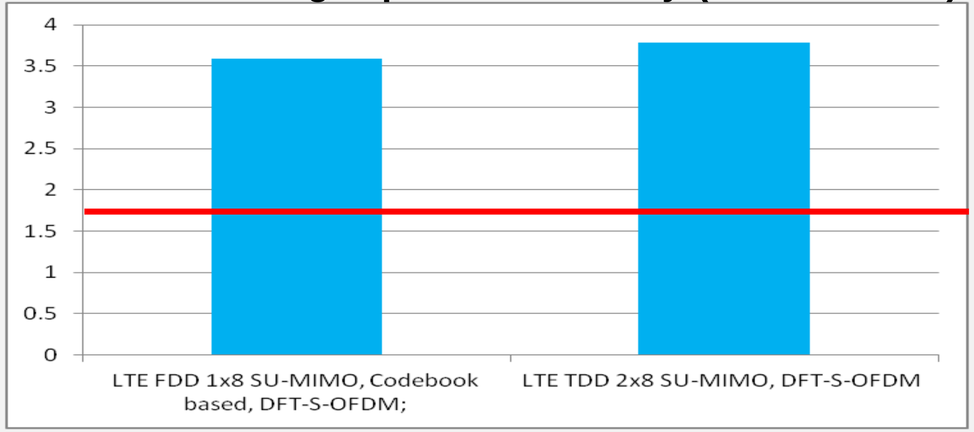


LTE DL 5th percentile user spectral efficiency (bit/s/Hz)

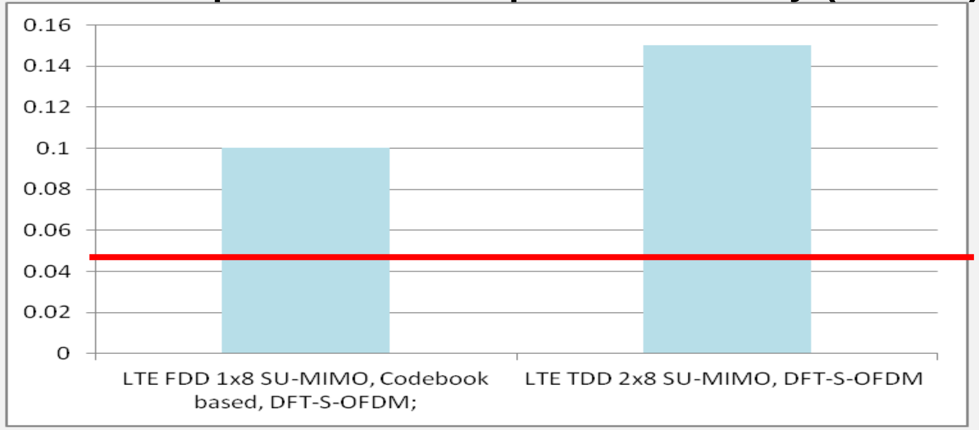


UL

LTE UL average spectral efficiency (bit/s/Hz/TRxP)



LTE UL 5th percentile user spectral efficiency (bit/s/Hz)



Preliminary evaluation on

User experienced data rate

- **Contributing technical components :**
  - For both DL and UL, carrier aggregation can be used to boost the user experienced data rate.
  - For the case of where NR TDD band is in higher frequency range, TDD+SUL can benefit UL user experienced data rate :
    - ✓ ***Usually TDD band is in higher frequency range than SUL band.***
    - ✓ ***In this case, cell edge users can be allocated to SUL band for uplink transmission where lower propagation loss is observed.***
  - … …

Required bandwidth for user experienced data rate (Dense Urban)

Target	Band	Required BW
DL target = 100 Mbit/s	4 GHz (NR FDD/TDD; various antenna configuration)	160~440 MHz BW
UL target = 50 Mbit/s	4 GHz (NF FDD/TDD; various antenna configuration)	120 ~ 800 MHz BW
	30 GHz (NR TDD, 8x32) + 4 GHz (SUL, 2x32)	30 GHz: 1.2 GHz BW; 4 GHz: 100 MHz BW

NR fulfills user experienced data rate requirement with its supported bandwidth capability.

Preliminary evaluation on

Area traffic capacity

- **Area traffic capacity:**

Area traffic capacity=
(Average SE) x (Aggregated bandwidth)
/ (Simulation area)

- NR Max aggregated bandwidth :
  - ✓ **FR1 (15 kHz SCS):** 16 CC x 50 MHz/CC = ***800 MHz***
  - ✓ **FR1 (30/60 kHz SCS):** 16 CC x 100 MHz/CC = ***1.6 GHz***
  - ✓ **FR2 (120 kHz SCS):** 16 CC x 400 MHz/CC = ***6.4 GHz***

Required bandwidth for area traffic capacity (Indoor hotspot)

Frequency band	Required BW for DL target of 10 Mbit/s/m^2	
	12TRxP	36TRxP
4 GHz	360 MHz ~ 600 MHz	120 MHz ~ 280 MHz
30 GHz	400 MHz ~ 800 MHz	200 MHz ~ 400 MHz

NR fulfills area traffic capacity requirement with its supported bandwidth capability.

Preliminary evaluation on
Energy efficiency

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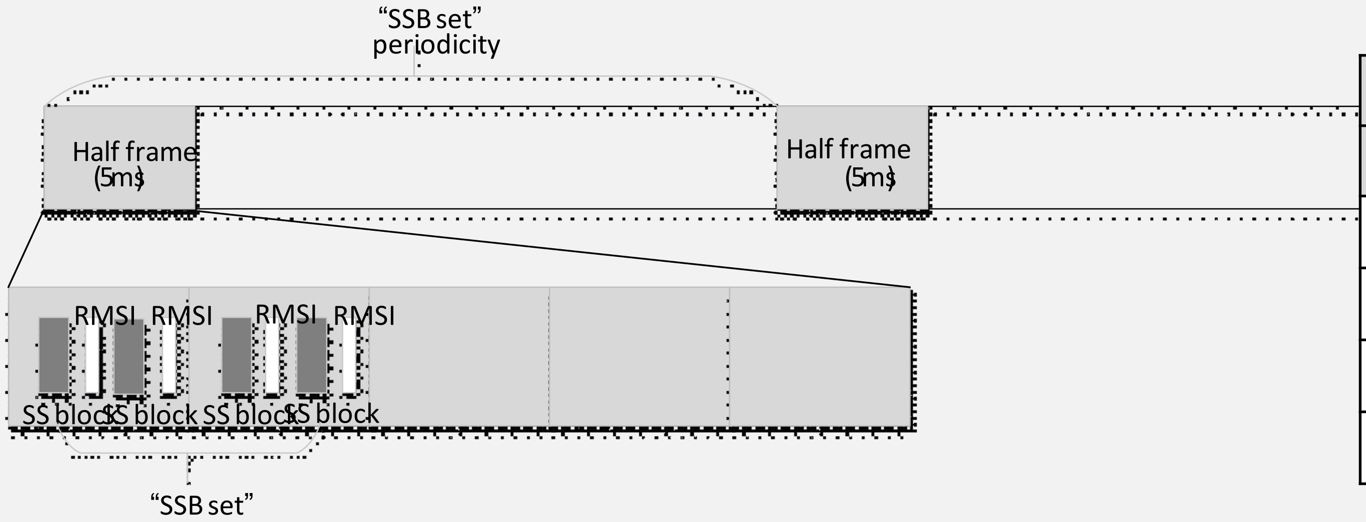
- Network energy efficiency
  - Related to always-on transmissions; For NR, SSB period can be configured as long as 160ms



NR gNB sleep ratio under low load

SSB configuration		SSB set periodicity P_{SSB}
SCS [kHz]	**Number of SS/PBCH block per SSB set, *L***	160ms
15kHz	1	99.38%
	2	99.38%
30kHz	1	99.84%
	4	99.38%
120kHz	8	99.69%
	16	99.38%
240kHz	16	99.69%
	32	99.38%

- Device energy efficiency
  - Discontinuous reception (DRX)
  - BWP adaptation for NR
  - RRC_INACTIVE state for NR

NR Device sleep ratio for idle / in-active mode

	Paging cycle N_{PC_RF} *10 (ms)	SCS (kHz)	SSB L	SSB reception time(ms)	SSB cycle (ms)	Number of SSB burst set	RRM measurement time per DRX (ms)	Transition time(ms)	Sleep ratio
RRC-Idle/Inactive	320	240	32	1	--	1	3.5	10	95.5%
	2560	15	2	1	--	1	3	10	99.5%
	2560	15	2	1	160	2	3	10	93.2%

NR fulfills energy efficiency requirement.

Preliminary evaluation on Energy efficiency

– Network energy efficiency

- For LTE, FeMBMS/Unicast-mixed cell and MBMS-dedicated cell can switch off the always-on signals.

LTE eNB sleep ratio under low load

Cell type	Sleep ratio
FeMBMS/Unicast-mixed cell	80%
MBMS-dedicated cell	93.75%

– Device energy efficiency

- Discontinuous reception (DRX)

LTE Device sleep ratio under idle mode

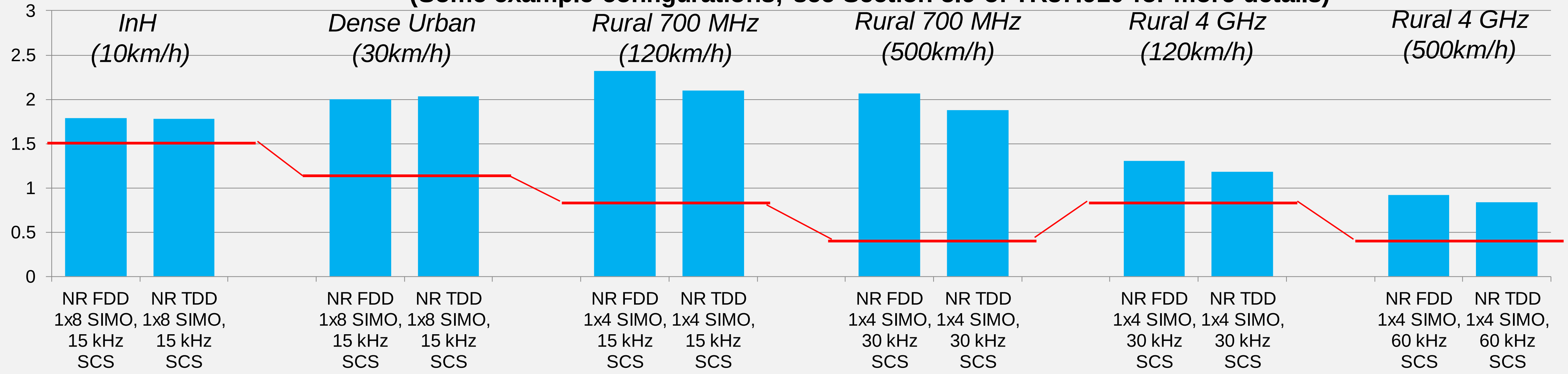
	Paging cycle N_{PC_RF} *10 (ms)	Synchronization reception time per cycle(ms)	Synchronization cycle(ms)	Number of synchronization	RRM measurement time per DRX (ms)	Transition time (ms)	DL/UL subframe ratio	Sleep ratio
RRC-Idle	320	2	10*	1	6	10	1	93.1%
	320	2	10*	2	6	10	1	90.0%
	2560	2	10*	1	6	10	1	99.1%
	2560	2	10*	2	6	10	1	98.8%

LTE fulfills energy efficiency requirement.

Preliminary evaluation on Mobility

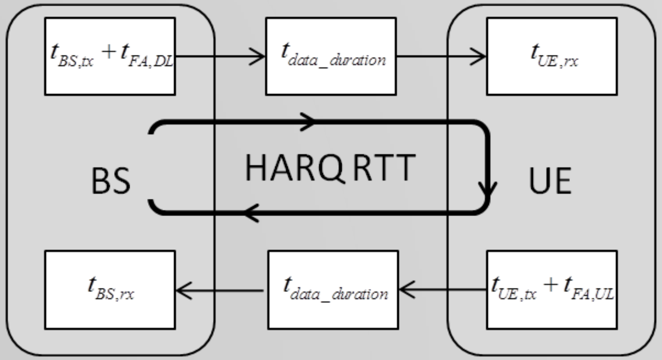
- **Mobility is evaluated using MIMO configurations**
- **Contributing technical components:**
  - *NR frame structure:*
    - ✓ NR multiple SCSs allow to use larger sub-carrier spacing which is beneficial to combat with Doppler spread.
    - ✓ NR fast CSI feedback and low processing delay helps to combat with time variation of propagation channel.

NR Mobility: Normalized traffic channel link data rate (bit/s/Hz)
(Some example configurations; see Section 5.9 of TR37.910 for more details)



Preliminary evaluation on
User plane latency

- **Contributing technical components for NR:**
  - *NR frame structure:*
    - ✓ NR larger SCSs allow slot duration reduction.
    - ✓ NR non-slot allows to use less number of OFDM symbol for data transmission, also beneficial to reduce air-interface transmission duration
    - ✓ Resource mapping type B allows immediate data transmission once scheduling resource is available.
  - *NR Flexible configuration of DL/UL slot:*
    - ✓ beneficial to reduce DL or UL waiting time
  - *NR TDD+SUL:*
    - ✓ SUL provided continuous uplink transmission opportunity to reduce DL ACK feedback and UL waiting time.
    - ✓ This is especially useful for synchronized network with DL dominant configurations (e.g., DDDSU).
  - … …

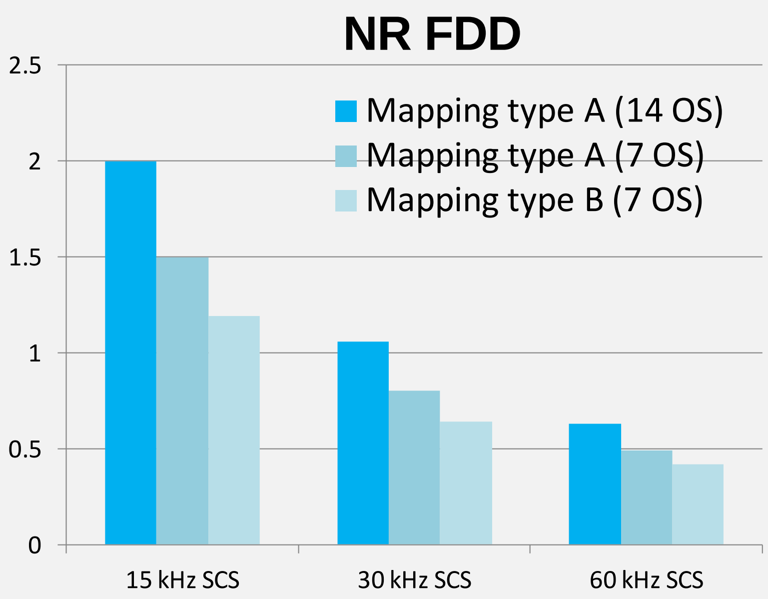


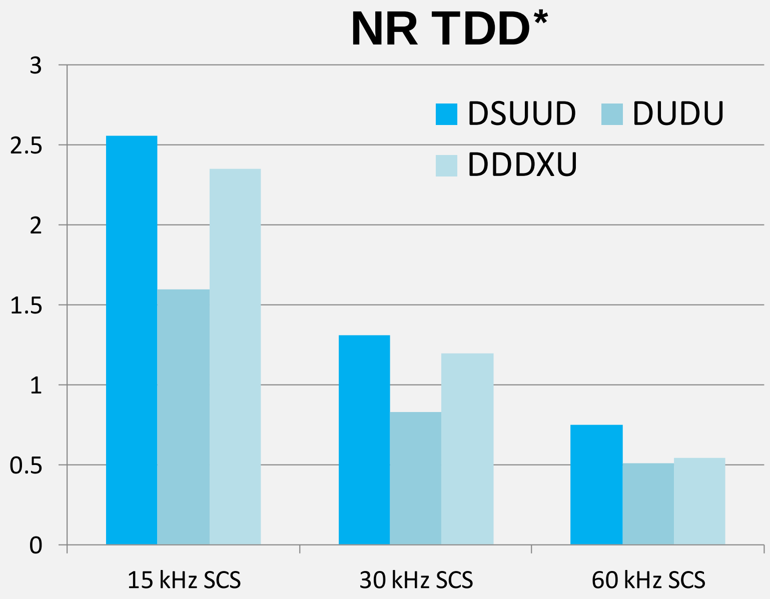
- **Contributing technical components for LTE:**
  - *Short TTI*
  - … …

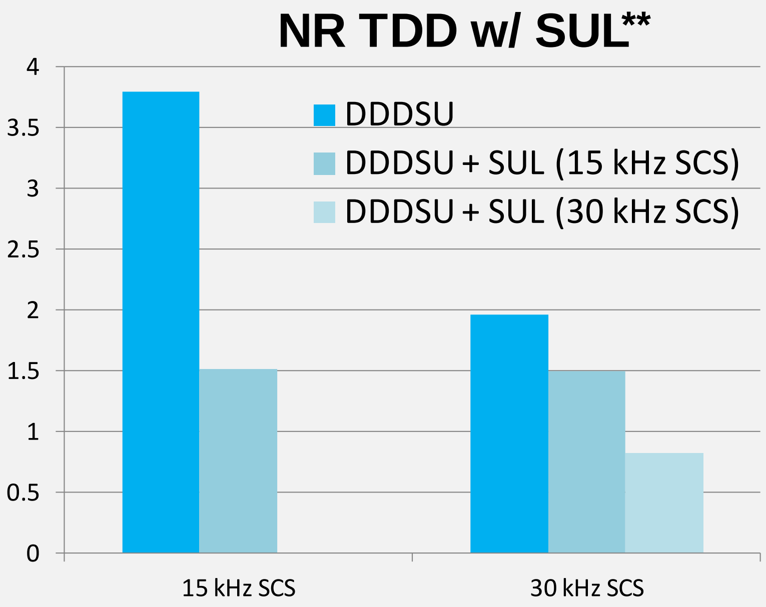
Preliminary evaluation on User plane latency

- Various configurations are evaluated for NR. See Section 5.7 of TR37.910 for more details.

UL UP latency for NR







* Mapping type B (7 OS)
** Mapping type A (7 OS)

NR fulfills UL user plane latency requirement for eMBB (4ms).

Preliminary evaluation on User plane latency

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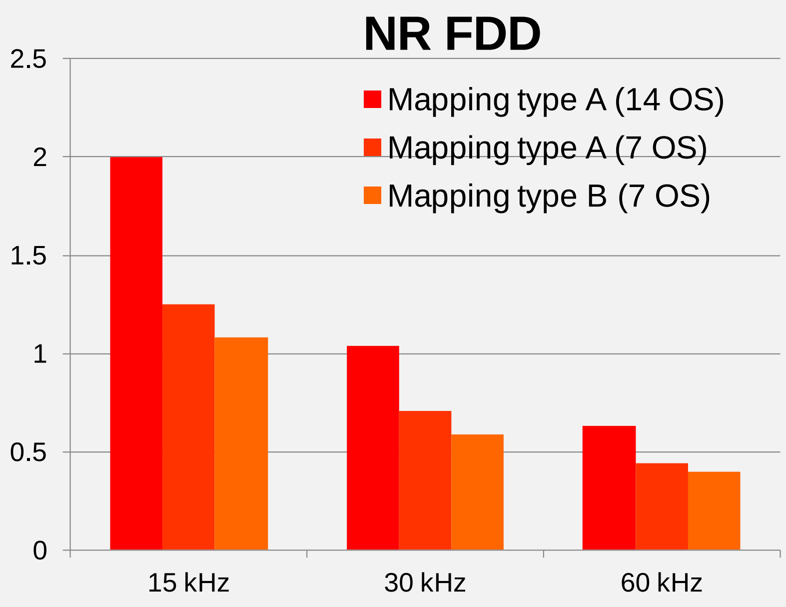
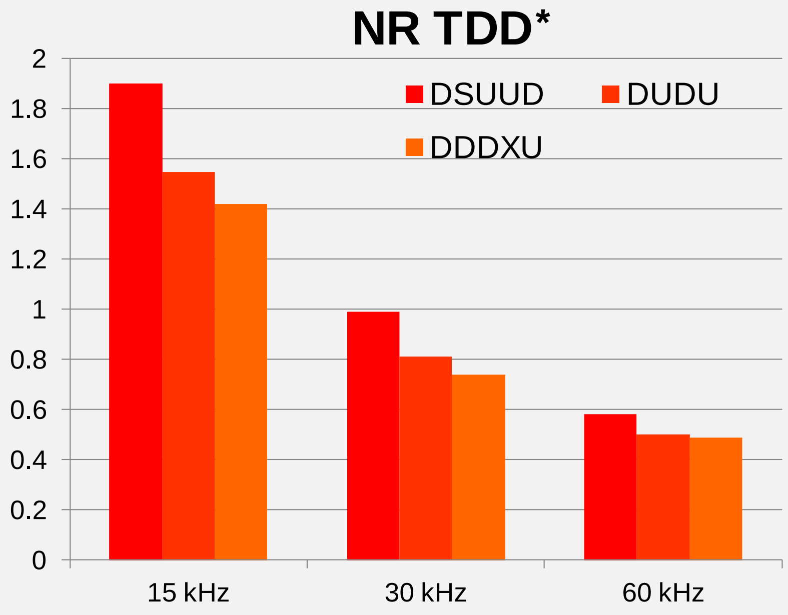
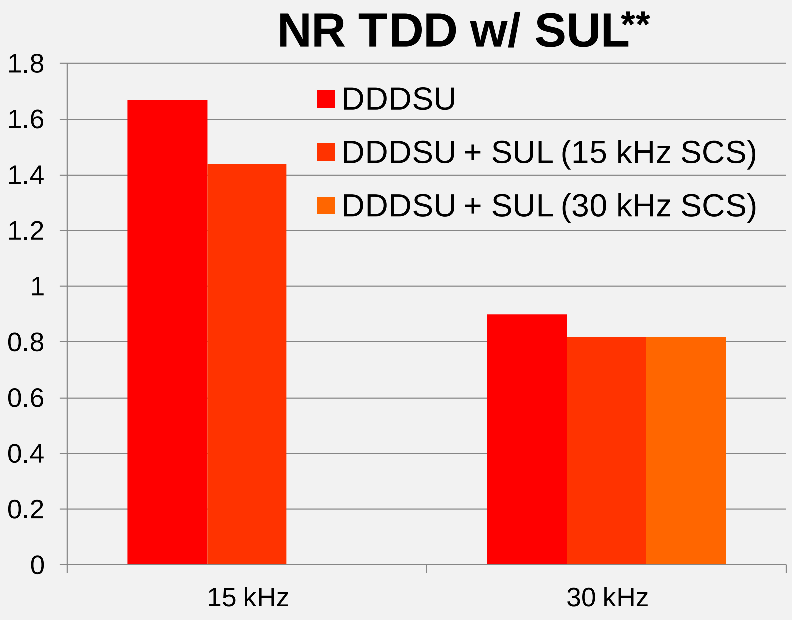
- Various configurations are evaluated for NR. See Section 5.7 of TR37.910 for more details.

DL UP latency for NR







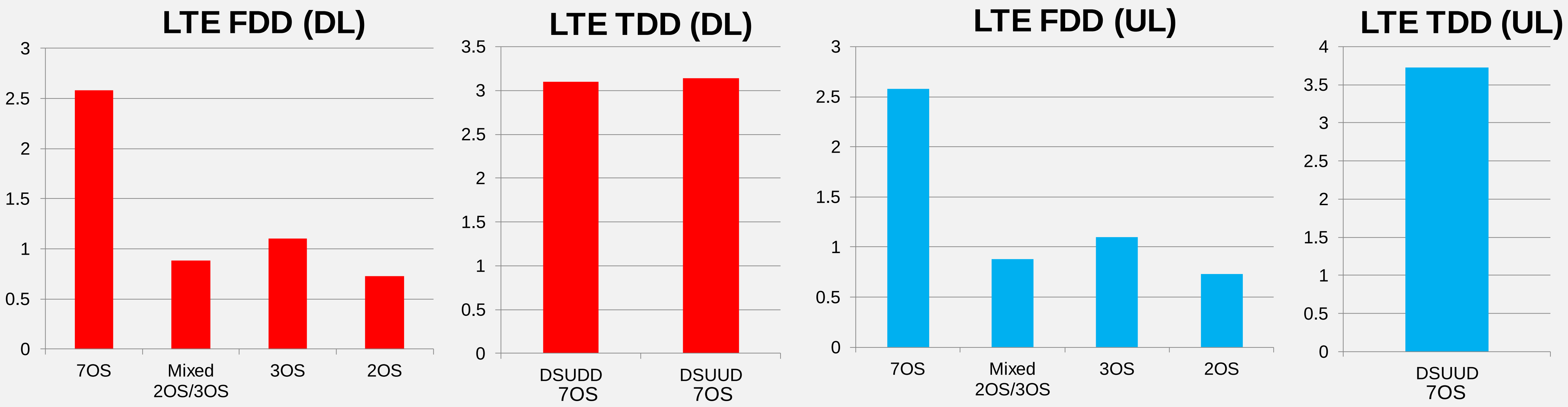
* Mapping type B (7 OS)
** Mapping type A (7 OS)

NR fulfills DL user plane latency requirement for eMBB (4ms).

Preliminary evaluation on
User plane latency

- Various configurations are evaluated for LTE. See Section 5.7 of TR37.910 for more details.

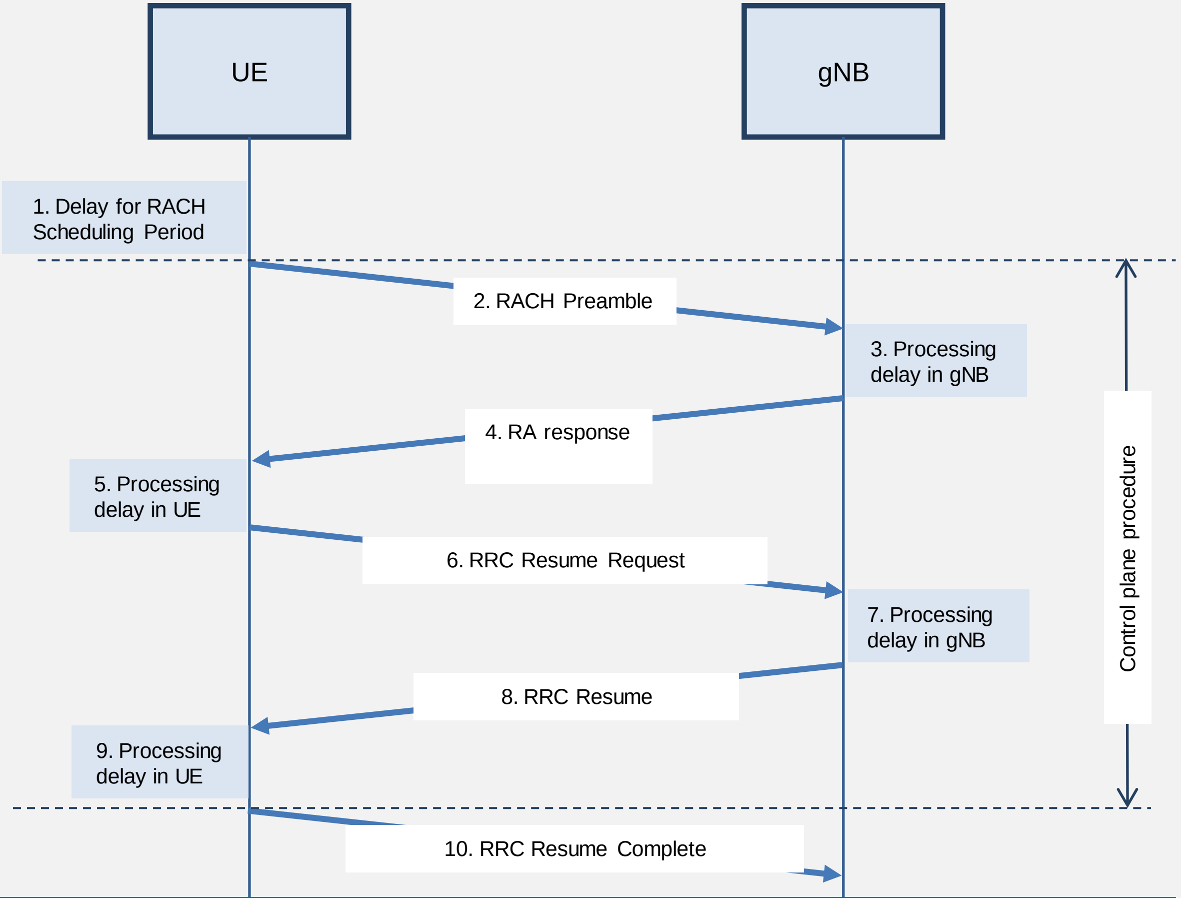
UP latency for LTE



LTE fulfills DL and UL user plane latency requirement for eMBB (4ms).

Preliminary evaluation on Control plane latency

- **Contributing technical components for NR include the use of RRC_INACTIVE state, as well as other components similar to UP latency.**
- **For LTE, the control plane latency is improved compared to Rel-10 by the use of RRC connection resume procedure, as well as by recognizing that some processing delay can be further reduced.**



NR

- **Both FDD and TDD can reach as low as around 11ms**

LTE

- **Both FDD and TDD can reach the target: 20ms**

NR and LTE fulfill control plane latency requirement for eMBB (20ms).

Preliminary evaluation on

Mobility interruption time

NR

NR fulfills 0ms mobility interruption time in the following scenarios:

- **Beam mobility**
  - ✓ When moving within the same cell, the transmit-receive beam pair of the UE may need to be changed.
  - ✓ gNB can configure different beams for this UE at different slots. It ensures appropriate transmit/receive beam allocation to the UE for continuous data transmission
- **CA mobility**
  - When moving within the same PCell with CA enabled, the set of configured SCells of the UE may change.
  - During these procedures, the UE can always exchange user plane packets with the gNB during transitions, because the data transmission between the UE and the PCell is kept.

LTE

LTE fulfills 0ms mobility interruption time in the following scenarios:

- **PCell mobility**
  - ✓ See details in Section 5.10 in TR37.910
- **DC mobility**
  - ✓ See details in Section 5.10 in TR37.910.

NR and LTE fulfill mobility interruption time requirement for eMBB (0ms).

Summary

- 3GPP provided preliminary self evaluation for NR and LTE (Rel-15) against IMT-2020 eMBB technical performance requirements.
- Preliminary evaluation shows that 3GPP 5G SRIT and RIT meet eMBB requirements.

Usage scenario	Sub-items	Evaluation method	Test environment		
			eMBB		
			Indoor hotspot	Dense urban	Rural
eMBB	Peak data rate	Analysis	NR, LTE		
	Peak spectral efficiency	Analysis	NR, LTE		
	User experienced data rate	Analysis, or SLS (for multi-layer)		NR	
	5th percentile user spectral efficiency	SLS	NR	NR	NR, LTE
	Average spectral efficiency	SLS	NR	NR	NR, LTE
	Area traffic capacity	Analysis	NR		
	Energy efficiency	Inspection	NR, LTE		
	Mobility	SLS + LLS	NR	NR	NR, LTE
	User plane latency	Analysis	NR, LTE		
	Control plane latency	Analysis	NR, LTE		
	Mobility interruption time	Analysis	NR, LTE		

THANK YOU

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