

Detailed views on NR UE feature list

Huawei, HiSilicon

Overview of RAN1-led NR features

- **0. Waveform, modulation, subcarrier spacings, and CP**
 - › Pi/2- BPSK optional [0-5, 0-12]
 - › 60kHz[0-10] and ECP[0-11] mandatory
- **1. Initial access and mobility**
 - › CSI-RS based RRM/RLM/BM mandatory [1-6,1-7,1-8]
- **2. MIMO/RS**
 - › 4 layer PDSCH reception at the UE as mandatory[2-1c]
 - › PRB bundling with size 2/4
 - › DMRS config. with up to 12 orthogonal ports[2-2a, 2-7a]
 - » Support both configurations type 1 and type 2
 - › 2 layer PUSCH transmission at the UE as mandatory[2-4b]
 - › CSI-RS based beam management as mandatory
 - › DL Codebook: Type-I up to 16 ports and A subset of Type II feedback schemes can be mandatory[2-12/13]
 - › PTRS as mandatory at least for high frequency[2-15/16]
 - › CSI-RS for fine time and frequency tracking (TRS) as mandatory[2-17]
 - › SRS antenna switching and carrier-based switching as mandatory[2-19]
- **3. Scheduling and HARQ**
 - PDCCH monitoring[3-3] and Blind Decoding[3-5], UE Processing Time[3-27] as capability, Soft Buffer Size[3-26]
 - Grant-free type I mandatory [3-32, 3-33]
 - A-CSI on short PUCCH mandatory[3-19]
 - TDD and Group-common PDCCH [3-46]
- **4. CA/DC, BWP, SUL**
 - BWP adaptation mandatory[4-2]
 - SUL [4-10]
- **5. Channel coding mandatory [5-1]**
- **6. UL TPC[6-1, 6-2]**

*The feature numbers are according to R1-1721707, “RAN1 UE feature list on Rel-15 NR”

WF, modulation, SCS and CP

Optional: $\pi/2$ BPSK [0-5, 0-12]

- **$\pi/2$ BPSK w./w.o FDSS**

- › The output power boosting resulting from $\pi/2$ BPSK w./w.o FDSS highly depends on the UE max. power limit, PA characteristics and RF requirement

- » In LTE, RAN1 #48 concluded that none of $\pi/2$ BPSK or FDSS (frequency domain spectrum shaping) are supported in LTE UL, considering the following response from RAN4

- It is possible to achieve the nominal maximum output power with LTE PA for QPSK without FDSS assuming a low number of resource blocks

- it is not feasible to increase the UE output power beyond the maximum nominal output power due to the regulatory requirements and co-existence issues.

- » In NR, the evaluation results show that $\pi/2$ BPSK w./w.o FDSS can bring potential benefit for below 6GHz HPUE (26dBm max. output power) and above 6GHz UE, while it highly depends on the PA characteristics and RF requirements on ACLR and EVM. Therefore, $\pi/2$ BPSK support is up to UE implementation

- › $\pi/2$ BPSK will increase testing complexity if mandatory

- › $\pi/2$ BPSK w./w.o FDSS should be optional as UE capability

Mandatory: 60kHz [0-10]

Benefits of 60KHz

- For URLLC

- › 60kHz numerology can allow for relaxed hardware processing to meet 0.5ms URLLC latency than 30 kHz numerology
- › 60kHz can provide better performance (2-3dB)

- For eMBB

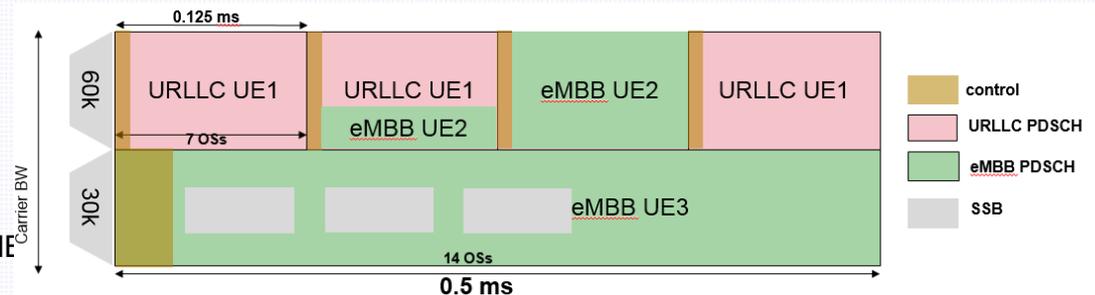
- › Better (3-5dB) link performance for high speed scenario
- › Better (12-16%) user throughput gain for low to medium traffic load
- › 60kHz agreed as mandatory for mm-wave, it is straight forward to support 60kHz for those UE which support mm-wave

- URLLC coexistence with eMBB

- › In a carrier, URLLC traffic can be flexibly scheduled in 60kHz BW part
 - › 60kHz numerology provides more flexible scheduling opportunity for URLLC
 - › 60kHz BW part does not contain SSB, hence, resource allocation is less constrained
- › Regular/Large eMBB traffic can be scheduled in 30kHz or 15kHz BW part with slot-level TTI
- › For dynamic resource sharing, eMBB traffic can be opportunistically scheduled in 60kHz BW part

Forward compatibility issues:

- If NR does not support 60kHz SCS, forward compatibility issues would occur for URLLC, eMBB, URLLC and eMBB coexistence and unlicensed operations.

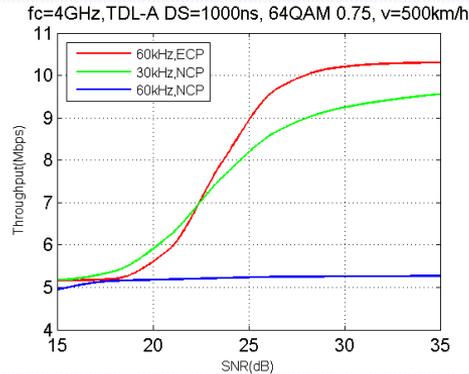


Mandatory: 60kHz ECP [0-11]

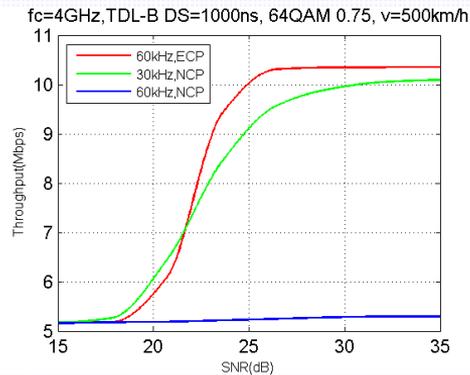
- **Use cases for ECP**

- Multiplexing of eMBB and URLLC deployed below 6GHz
- Transmission of URLLC with 60 kHz subcarrier spacing
- High speed scenario for 30 kHz and 60 kHz (including SFN and Non-SFN)

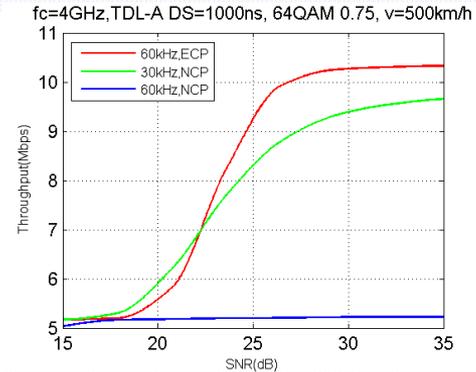
- **60kHz ECP can provide larger gain in SFN and Non-SFN high speed scenarios**



Non-SFN TDL-A



Non-SFN TDL-B



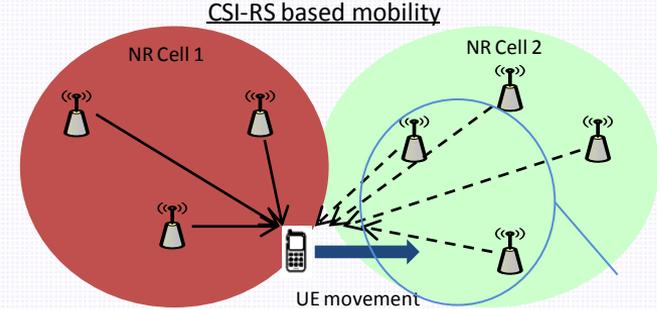
SFN TDL-A

- All UE need to support 60kHz ECP for long delay spread scenarios

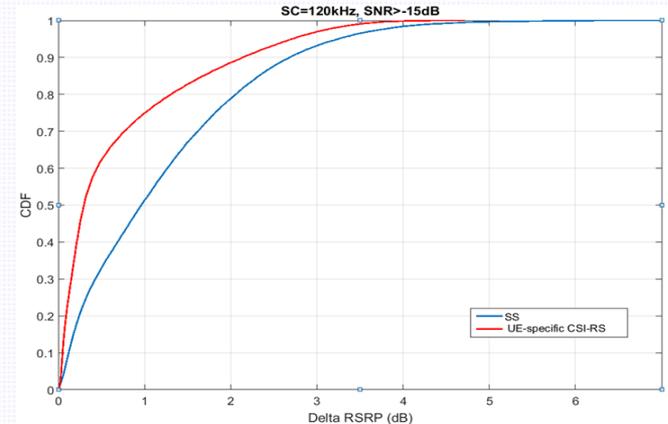
**IAM: CSI-RS based RRM/RLM/BM
mandatory**

Mandatory: CSI-RS based RRM/RLM/BM [1-6,1-7,1-8]

- Application Scenarios
 - › Efficient for NR deployment supporting TRPs in SFN (specifically of SS/PBCH blocks) operation
 - » CSI-RS for mobility from the target cell can be configured in the handover command (and the associated dedicated PRACH preambles). Target cell can establish the right TRP(s) based on the CSI-RS association with RACH preamble.
 - › Secondary Carrier could be without SS Blocks (e.g. non-contiguous intracell CA). For efficient HO or carrier activation/deactivation, CSI-RS needs to be configured in these Scells.
- Benefit of CSI-RS for RRM and RLM:
 - › Allow networks to configure SS Blocks burst set periodicity up to 160ms for power efficient network operations.
 - › Per UE, CSI-RS can be configured in wider bandwidth and on a per need basis providing improved RSRP and RSRQ accuracy.
 - › Provide an accurate RLM i.e. CSI-RS can be sent in narrower beam compared to SS-RS for RLM. This improves the hypothetical PDCCH BLER in addition to shorter monitoring time for UE due to shorter CSI-RS periodicities.



After hand-over, network can immediately establish UE-specific TRP(s) for data communication



CSI-RS can be configured in wider bandwidth “as needed”, providing improved RSRP accuracy.

MIMO/RS

Overview of MIMO/RS

- 4 layer PDSCH reception at the UE as mandatory[2-1c]
- PRB bundling with size 2/4
- DMRS configurations with up to 12 orthogonal ports [2-2a,2-7a]
 - › Support both configurations type 1 and type 2
- 2 layer PUSCH transmission at the UE as mandatory[2-4b]
- CSI-RS based beam management as mandatory
- DL Codebook: Type-I up to 16 ports and a subset of Type II feedback schemes can be mandatory [2-12/13]
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- SRS antenna switching and carrier-based switching as mandatory [2-19]

Mandatory: DMRS configuration type 2 [2-2a, 2-7a]

	DMRS configuration Type 1	DMRS configuration type 2
Main Features	<ul style="list-style-type: none">• Max 8 orthogonal ports for MU• Max 4/8 ports for DL SU• Comb 2 + 2 CS + (TD-OCC)	<ul style="list-style-type: none">• Max 12 orthogonal ports for MU• Max 6/8 ports for DL SU• 2-FD-OCC across adjacent REs + (TD-OCC)
Throughput	Lower throughput performance <ul style="list-style-type: none">• Smaller number of ports• [More quasi-orthogonal layers]	Higher throughput performance <ul style="list-style-type: none">• Larger number of ports• [Fewer quasi-orthogonal layers]• 15%~20% mean UPT gain for 4Rx UE and 17%~29% mean UPT gain for 8Rx UE
Estimation Performance	Poor performance due to de-spreading loss: <ul style="list-style-type: none">• Unsuitable for large subcarrier spacing scenarios• Unsuitable for frequency-selective scenarios	Robust performance with higher de-spreading gain: <ul style="list-style-type: none">• Benefit to large subcarrier spacing scenarios• Benefit to frequency-selective scenarios• ~1dB SINR gain @60KHz SCS or 1000ns delay spread
Reception Complexity	Higher channel estimation complexity <ul style="list-style-type: none">• Limits PRB bundling size	Lower channel estimation complexity <ul style="list-style-type: none">• Can support larger bundling size

- All UE need to support DMRS configuration type 2 in terms of performance and reception complexity.

Mandatory: Type 2 Codebook [2-12/13]

	Cell average gain	Cell edge gain
4T2R	~18%	~27%
32T2R	~35%	~49%

- UE complexity comparison (8T2R, N1=N2=2, O1=O2=4, Rank1 feedback)
- Taking 10 subbands as an example
 - The total number of complex multiplication with Type I and Type II: **8120 and 2031**
 - Compared with Type I, the complexity at UE side for Type II is 25%

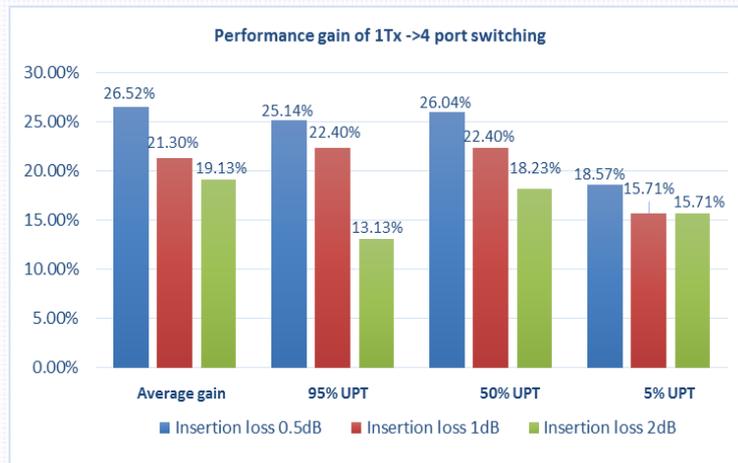
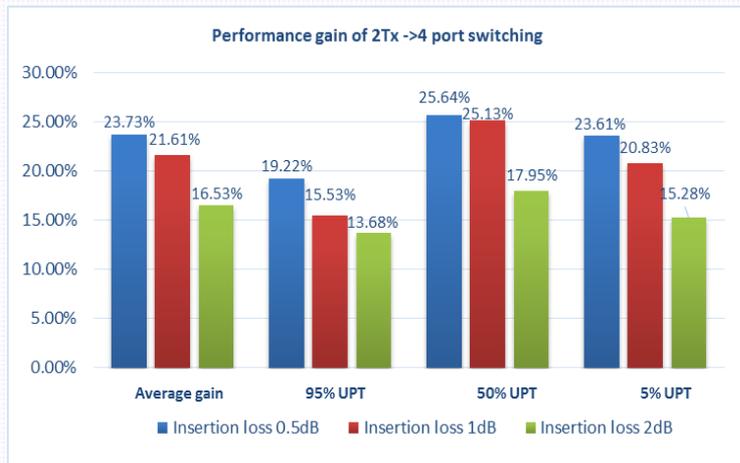
Payload size for 4 ports				
	Type I		Type II (L=2,W+S,8PSK)	
	WB-reporting	SB-reporting (10 subbands)	WB-reporting	SB-reporting (10 subbands)
Rank 1	5	23(L=1)/42(L=4)	24	135
Rank 2	6	15(L=1)/34(L=4)	44	266
Payload size for 8 ports (wideband)				
	Type I	Type II (L=2, W+S,8PSK)	Type II (L=3, W+S,8PSK)	Type II (L=4, W+S,8PSK)
Rank 1	8	27	39	49
Rank 2	9	47	72	94
Payload size for 8 ports (10 subbands)				
	Type I	Type II (L=2, W+S,8PSK)	Type II (L=3, W+S,8PSK)	Type II (L=4, W+S,8PSK)
Rank 1	26(L=1)/4 5(L=4)	138	184	268
Rank 2	18(L=1)/3 7(L=4)	269	362	532

- At least a subset of type II NP codebook should be as mandatory for UE capability.

Mandatory: SRS antennas switching [2-19]

- **Support higher rank DL transmission**

- With 4 Rx at UE side, support up to 4 layers DL transmission.
- In the TDD case, enable 4 antenna SRS switching (1T→4T or 2T→4T) for obtaining the full rank channel.



- About **23% mean UPT gain** can be observed over **2Tx switching** for 2T4R/UE
- About **26% mean UPT gain** can be observed over **1Tx switching** for 1T4R/UE

Scheduling and HARQ

PDCCH monitoring periodicity [3-3] and Blind Decoding [3-5]

- 3-3: Minimum PDCCH monitoring occasion for a CORESET should be defined for different SCS[R1-1719401] , i.e,
 - 2OSs for 15kHz SCS
 - 4OSs for 30kHz SCS
 - 7 OSs for 60kHz SCS
 - 14 OSs for 120kHz SCS
- 3-5: Scale the BD (blind decoding) capability with up to 4CC is acceptable. Otherwise, explicit UE capability on the maximum number of PDCCH blind decodes should be reported.

Max no. of PDCCH BDs per slot [R1-1800821]	SCS			
	15kHz	30kHz	60kHz	120kHz
Case 1-1	44	36	22	20
Case 1-2	[44]			-
Case 2	[44+X]	[36+Y]	[22+Y]	[20]

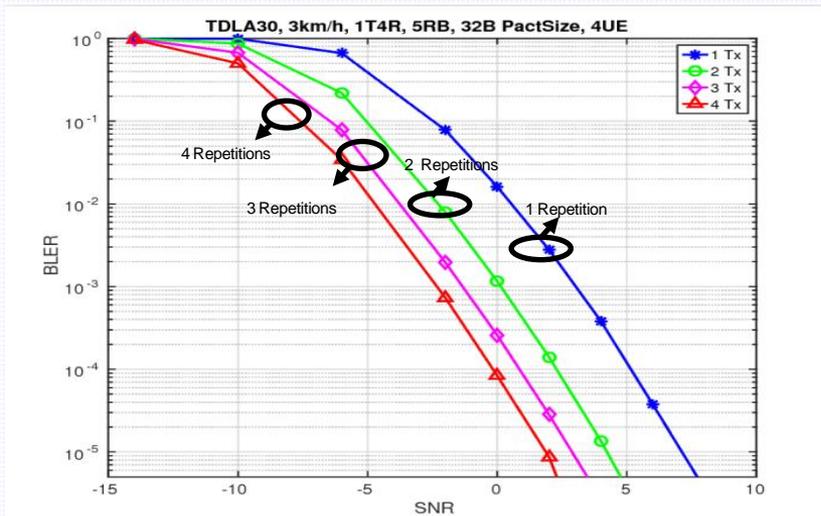
UE Soft Buffer Size [3-26]

- UE capacity depends on instant peak data rate and sustainable data rate.
 - › instant peak data rate depends on baseband processing capability
 - › sustainable data rate depends on UE soft buffer size, in addition to baseband processing capability
- **Proposal1a: NR Soft buffer dimensioning is derived from $(3 \cdot \text{reference_DataRate}/2) \cdot (\text{reference_DL_HARQ_RTT})$. The reference_DataRate is the peak data rate UE supported. The reference_DL_HARQ_RTT is defined as the maximum HARQ RTT corresponding to the peak data rate.**
- **Proposal1b: Report reference HARQ RTT as UE capability.**
- Define two types of LTE-NR DC UEs
 - › Type 1:with limited LTE-NR interworking capability
 - › Type 2:with tight LTE-NR interworking capability
- **Proposal 2: Report the soft buffer sharing mechanisms in LTE-NR DC operation mode as UE capability:**
 - **Dynamic sharing, semi-static sharing or hard splitting.**

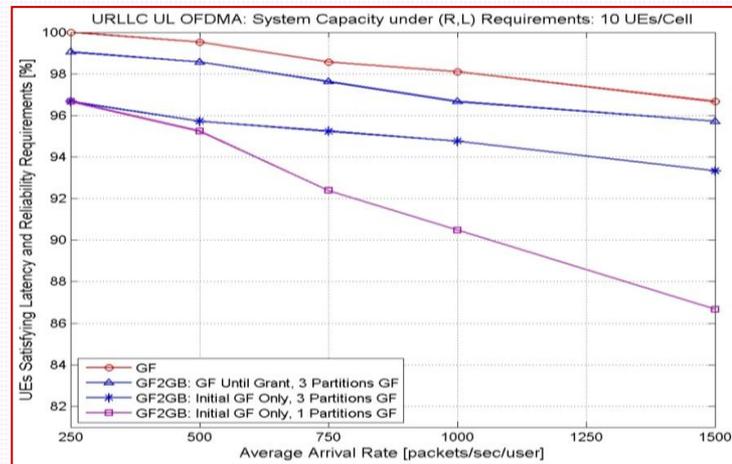
Mandatory: GF Type 1 and repetitions [3-32, 3-33] (1/2)

GF Type	Type Definition	Target Scenarios	Benefits
Type 1	<ul style="list-style-type: none"> Resource (re)configuration is only based on RRC signaling and no L1 signaling is needed 	<ul style="list-style-type: none"> low-latency and high-reliability services with sporadic and non-periodic packet arrivals, e.g., URLLC service Can also support services with periodic packet arrivals, e.g., VoIP Massive small packet transmissions with low cost and low signaling overhead in e.g., mMTC and eMBB scenarios 	<ul style="list-style-type: none"> [Latency] Simple resource (re-)configuration suitable for unknown traffic pattern (event driven and sporadic) and ultra low latency feature [Reliability] Simple resource (re-)configuration with Less L1 signaling overhead and reliability issue, especially for ultra high reliability cases [Service diversity] Simple resource configuration to support multiple configurations for different types of services with various latency and reliability requirements simultaneously in case the number of serving cells is limited [Energy saving] Simple resource configuration to avoid unnecessarily frequent DCI monitoring to save energy consumption for the massive MTC devices with latency budget [Efficiency] Allow contention to support higher resource utilization
Type 2	<ul style="list-style-type: none"> Resource (re)configuration is based on both RRC signaling and L1 signaling, where L1 signaling is used for resource activation/deactivation/modification 	<ul style="list-style-type: none"> Moderate-to-low-latency and reliability services Most likely for the case with known traffic patterns, e.g., periodic packets such as VoIP 	<ul style="list-style-type: none"> [Efficiency] Allow contention to support higher resource utilization [Flexible control] More flexible and dynamic for resource update when accurate CSI knowledge is available
LTE SPS	<ul style="list-style-type: none"> Semi-statically configured resource with DCI activation/deactivation 	<ul style="list-style-type: none"> Periodic traffic such as VoIP 	<ul style="list-style-type: none"> [Flexible control] More flexible and dynamic for resource update when accurate CSI knowledge is available

Mandatory: GF Type 1 and repetitions [3-32, 3-33] (2/2)



Performance improvement by HARQ combining



Latency reduction of GF-repetition over GB-Rx

- Proposal: 3-14 (DL SPS) is optional (not widely used in LTE). GF Type 1 is mandatory
- Proposal: K repetition should be mandatory for GF (no need for a UE feature separate than GF). If split number of repetitions into different UE features, then support at least k=4

Mandatory: A-CSI on short PUCCH [3-19]

- **Motivation 1: provide fast CQI feedback, such as $Y=0$**
 - Support CSI feedback in the same slot as DL grant
 - Provide in-time CSI feedback to enable fast link adaption for DL scheduling
 - Good for services like URLLC service requiring low latency
- **Motivation 2: suitable for beam reporting**
 - Only require lightweight CRI/RSRP feedback of around 10 bits for beam management
 - » Beam management procedures are mainly based on aperiodically triggered beam sweeps
- **Motivation 3: beneficial for DL heavy case**
 - Overhead for A-CSI on short PUCCH is smaller than A-CSI on PUSCH
 - Uplink portions of slots may not be long enough for long PUCCH and long PUSCH
 - Can configure more short UL portions for low latency (HARQ, CSI)

TDD: Operation modes for NR [3-46/47]

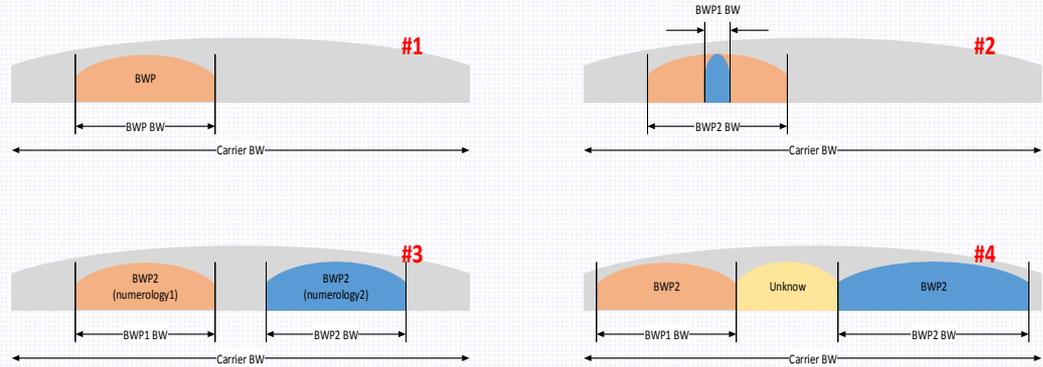
- **During offline discussion, it was proposed that NR supports the following operation modes:**
 - › Semi-static SFI configuration without dynamic SFI
 - › Dynamic SFI without semi-static SFI configuration
 - › Semi-static SFI configuration with dynamic SFI
 - › No semi-static SFI configuration and no dynamic SFI
 - » All transmission direction via DCI and/or configured periodic DL/UL signals
- **Proposal: Operation mode 4 (i.e. no semi-static SFI configuration and no dynamic SFI) should NOT be assumed as a typical network operation (or supported as optional)**
 - Note: Both semi-static operation (operation mode 1) and dynamic operation (operation mode 2/3) are beneficial for NR thus should be supported in NR

CA/DC, BWP, SUL

Mandatory: BWP adaptation [4-2]

Scenarios

- Scenario#1 (agreed): Supporting reduced UE BW capability
- Scenario#2 (agreed): Supporting reduced UE energy consumption by mean of bandwidth adaptation
- Scenario#3 (agreed): Supporting FDM of different numerologies
- Scenario#4: not support as a wideband carrier, support it as non-contiguous intra-band carrier aggregation



Merits of BWP adaptation

- Scenario#2 : UE power saving (20-90% power saving depend on the ratio of wider BWP and narrow BWP)
 - Adjust the RF bandwidth to reduce the energy consumption.
 - Small bandwidth for PDCCH monitoring and low data rate transmission
 - Large bandwidth for PDSCH with large traffic
- Scenario#3: Dynamic resource sharing
 - Enable resource sharing for different BWP with different numerology
 - eMBB UE can share the resource with URLLC BWP
 - Low latency eMBB traffic can share its resource to large latency eMBB traffic

SUL and UL sharing [4-10]

- **Feature x-0: 7.5kHz shift for SUL bands in which UL sharing is possible, if the UE supports the SUL bands**
 - › At least the already agreed, mandatory 6 SUL bands n80 – n85 are SUL bands in which UL sharing is possible
 - › Additional SUL bands shall be identified as soon as possible
 - › Prefer “mandatory” for all LTE re-farmed bands
- **Feature x-1: A UE supporting a SUL band combination is mandatory to support the following (with Feature x-0 as a pre-requisite if the SUL band is possible for UL sharing)**
 - › RACH, PUSCH, PUCCH, SRS operations on SUL and non-SUL of the same cell
 - › Same and different numerologies between DL/non-SUL and SUL of the same cell
 - › DCI based PUSCH scheduling on SUL and non-SUL of the same cell
- **Feature x-2: Switching time between LTE UL and NR UL on the same UL**
 - › UE shall report one of “~0us” and “<20us”
 - › Per UE capability, i.e. same capability applies to all EN-DC band combinations supported by the UE, in which NR SUL overlaps with LTE UL
- **Feature x-3: Switching time between NR SUL and NR non-SUL of the same cell**
 - › No agreed switching time so far
 - › Per SUL band combination capability and may not need UE capability signaling, i.e. all UEs supporting the same SUL band combination shall support the same switching time between NR SUL and NR non-SUL

Thank you !