

Agenda Item: 1
Source: Chairman
Title: Agenda of the Workshop on 3GPP submission towards IMT-2020
Document for: Approval

Chairman's foreword

Welcome to the Workshop on 5G NR IMT2020 evaluation intended to present the details of the 5G NR radio interface as per the 3GPP Release 15 completed standards and the Release 16 planned features.

3GPP has been working extremely hard to bring 5G NR standards to the industry in an accelerated manner. Non-standalone 5G NR was completed in December 2017, and the corresponding ASN.1 has been stabilized in June/2018.

Standalone 5G NR was completed in June/2018, and the corresponding ASN.1 scheduled to be frozen in September/2018.

Some of the architecture options to facilitate migration from LTE to 5G NR will be completed in December/2018 still within Release 15.

3GPP has also approved the work program for Release 16 containing a host of new and enhanced functionalities for 5G NR. The target completion for Release 16 is December/2019. 3GPP submission to IMT2020 will contain both Release 15 and Release 16 functionality.

Balazs Bertenyi, Chairman of 3GPP RAN.

- | | | |
|-----|-----------------------------------------------------------------------------------------|-------|
| 1 | Opening of the meeting (Wednesday 1pm) | 55min |
| 1.1 | Welcome from chairman of the workshop
(Balazs Bertenyi, 3GPP TSG RAN chairman) | 10min |
| 1.2 | Welcome from ITU-R WP5D
(Håkan Ohlsén, ITU-R WP5D vice chairman) | 10min |
| 1.3 | Welcome from the host (Pearse O'Donohue, European Commission) | 20min |
| 1.4 | Explanation of 3GPP submission
(Giovanni Romano, 3GPP TSG RAN ITU-R Ad hoc Convener) | 15min |

2	Specific technical features of the 3GPP proposal for 5G	265min
2.1	Overview	
2.1.1	RAN aspects (Balazs Bertenyi, 3GPP TSG RAN chairman)	20min+5QA
2.1.2	System and Core network aspects (Erik, Guttman, 3GPP TSG SA chairman)	20min+5QA
Wed afternoon coffee break (14:45-15:15)		
2.2	NR physical layer design	
2.2.1	Physical layer structure, numerology and frame structure, NR spectrum utilization mechanism (Havish Koorapaty, Ericsson)	40min+5QA
2.2.2	NR MIMO (Younsun Kim, Samsung)	25min+5QA
2.3	NR architecture (Gino Masini, 3GPP TSG RAN WG3 chairman)	25min +5QA
end of Wed (~17:00), beginning of Thu: 9:00		
2.4	NR protocol (Sudeep Palat, Intel)	25min+5QA
2.5	NR radio frequency and co-existence (Xutao Zhou, 3GPP TSG RAN WG4 chairman)	25min+5QA
2.6	NB-IoT, eMTC, and LTE evolution	
2.6.1	NB-IoT, eMTC (Matthew Webb, Huawei)	20min+5QA
Thu morning coffee break (10:30-11:00)		
2.6.2	LTE evolution (Asbjörn Grövlén, Ericsson)	20min+5QA
3	IMT-2020 submission templates	45min
3.1	Overview of 3GPP submission and compliance to IMT-2020 requirements (Wu Yong, Huawei)	10min+5QA
3.2	Description characteristics template (Kazuaki Takeda, NTT DOCOMO)	10min+5QA
3.3	Link budget template (Asbjörn Grövlén, Ericsson)	10min+5QA

4	Self-Evaluation results (including simulation assumptions and calibration)	120min
4.1	Calibration method and results (Francesco Pica, Qualcomm)	15min+5QA
Thu lunch break (12:30-14:00)		
4.2	eMBB evaluation results (Wu Yong, Huawei)	30min
4.3	URLLC and mMTC evaluation results (Karri Ranta-Aho, Nokia)	30min
4.4	General Q&A	40min
Thu afternoon coffee break (15:40-16:10)		
5	Anticipations on the final IMT-2020 submission: Rel-16 outlook	50min
5.1	RAN aspects (Balazs Bertenyi, 3GPP TSG RAN chairman)	20min+5QA
5.2	System and Core network aspects (Erik, Guttman, 3GPP TSG SA chairman)	20min+5QA
6	Closing of the meeting (Thursday 5pm)	



ITU-R Working Party 5D

Introduction to IMT-2020

October 24, 2018

Håkan Ohlsén

Vice-Chairman - ITU-R Working Party 5D

Stephen M. Blust, P.E.

Chairman - ITU-R Working Party 5D

Sergio Buonomo

Counselor – ITU-R Study Group 5



Two Key & Interrelated Focus Areas for IMT-2020 & 5G Success



- ITU WRC Process
 - Mobile spectrum allocations and IMT identifications
 - ITU membership, ITU-R Study Groups, Regional Groups, International organisations
 - Member States driven
- ITU-R Study Group 5 Process
 - IMT-2020 Vision, overall requirements, radio interface specifications
 - ITU membership, other standard making bodies
 - Industry driven
 - Reports & Recommendations approved by Member States



IMT-2020 radio interface standardization process

- ❖ Development plan
- ❖ Market/services view
- ❖ Technology/research kick off
- ❖ Vision - IMT for 2020
- ❖ Name
- ❖ Process optimization

- ❖ Technical performance requirements
- ❖ Evaluation criteria
- ❖ Invitation for proposals
- ❖ Sharing study parameters (IMT-2020)
- ❖ Sharing studies in preparation for WRC-19

- ❖ Technical proposals
- ❖ Evaluation Groups
- ❖ Methodology
- ❖ Consensus building

- ❖ Spectrum/band arrangements
- ❖ Decision & radio framework
- ❖ Detailed IMT-2020 radio specifications
- ❖ Future enhancement/update plan & process

IMT-2020 spectrum allocation process

- ❖ < 6 GHz Spectrum view
- ❖ ITU-R Study Group activities/studies
- ❖ Spectrum/band arrangements (post WRC-15)

- ❖ CPM Report (IMT- WRC-19)
- ❖ Sharing study reports
- ❖ Spectrum/band arrangements (WRC-19)

2012-2015

2016-2017

2018-2019

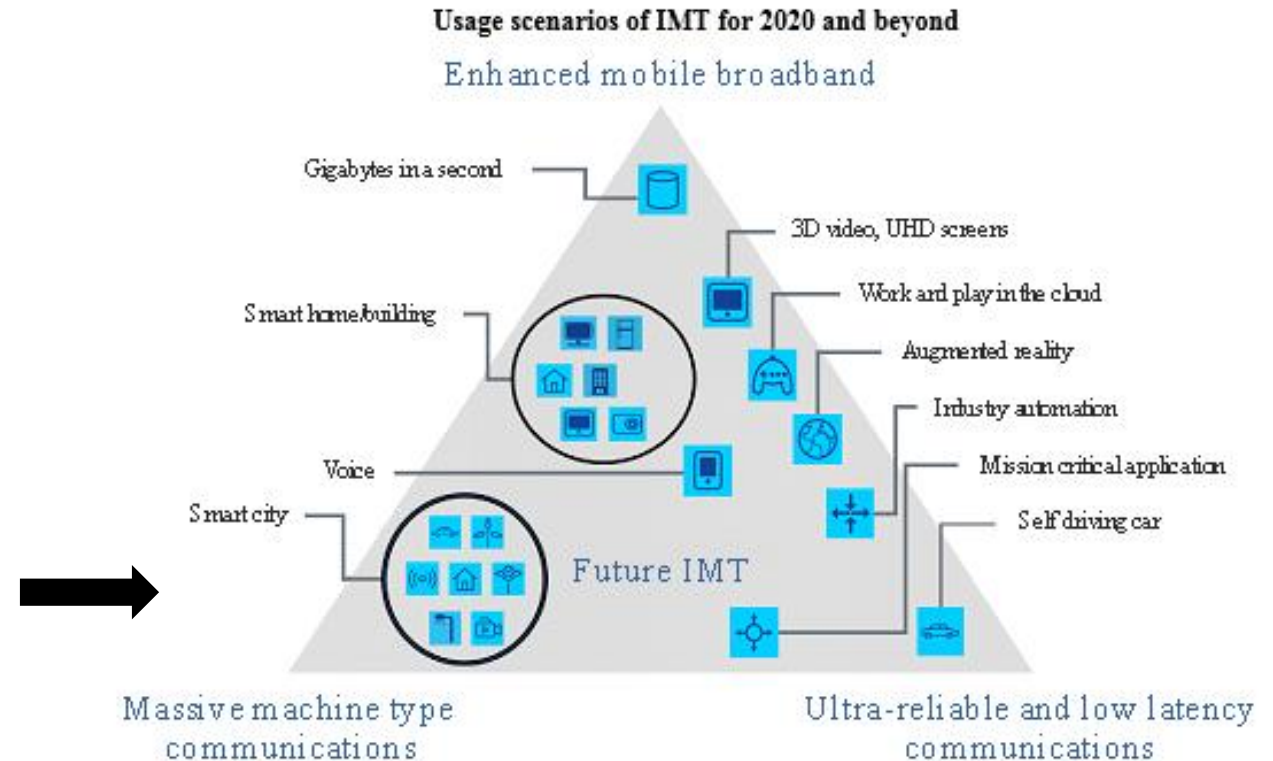
2019-2020

Setting the stage for the future:
vision, spectrum, and technology views

Defining the technology
Allocate the spectrum

ITU Perspective – IMT 2020 (International Mobile Telecommunication)

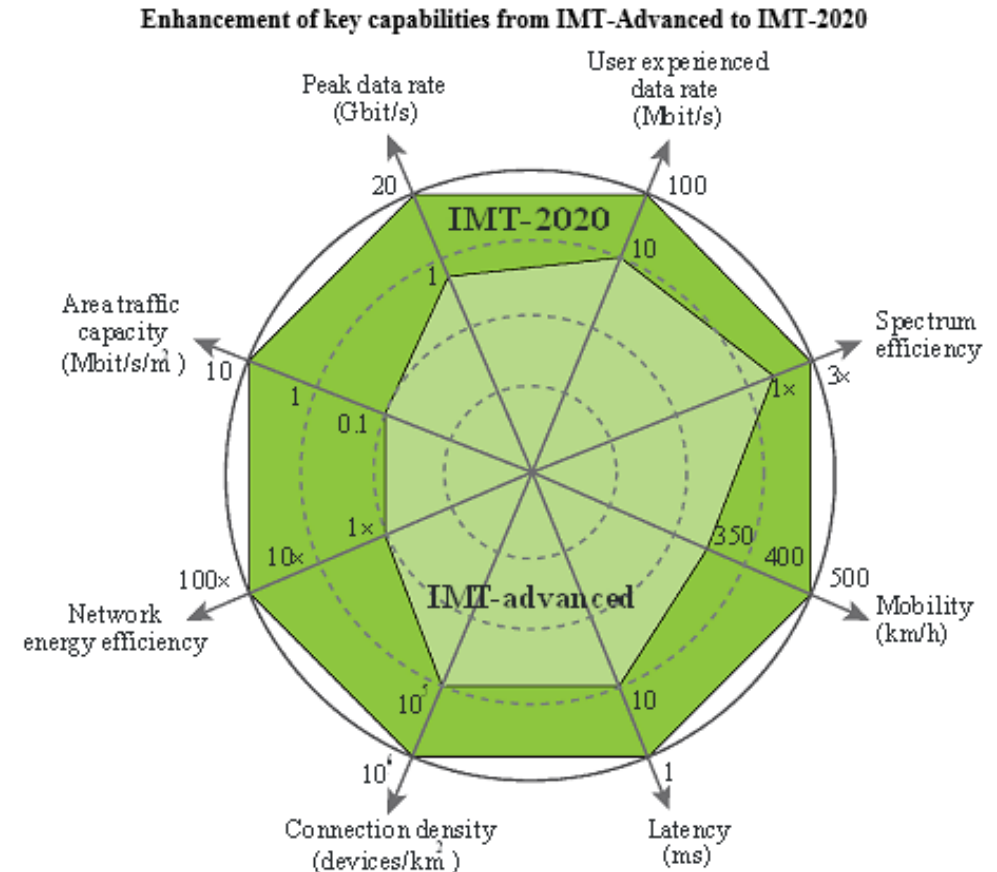
- Early 2012, ITU-R embarked on a global program to develop “IMT for 2020 and beyond”
 - Setting the stage for 5G research activities that are emerging around the world
 - [Report ITU-R M.2320](#) – “Future technology trends of terrestrial IMT systems” (Nov 2014)
- September 2015, ITU-R finalized “Vision” of the 5G mobile broadband connected society
- [Recommendation ITU-R M.2083](#) – “Framework and overall objectives of the future development of IMT for 2020 and beyond” (Sep 2015)
 - Defined the “usage scenarios” for IMT 2020 and beyond
 - Instrumental in setting the agenda for the World Radiocommunication Conference 2019



ITU 2013-02

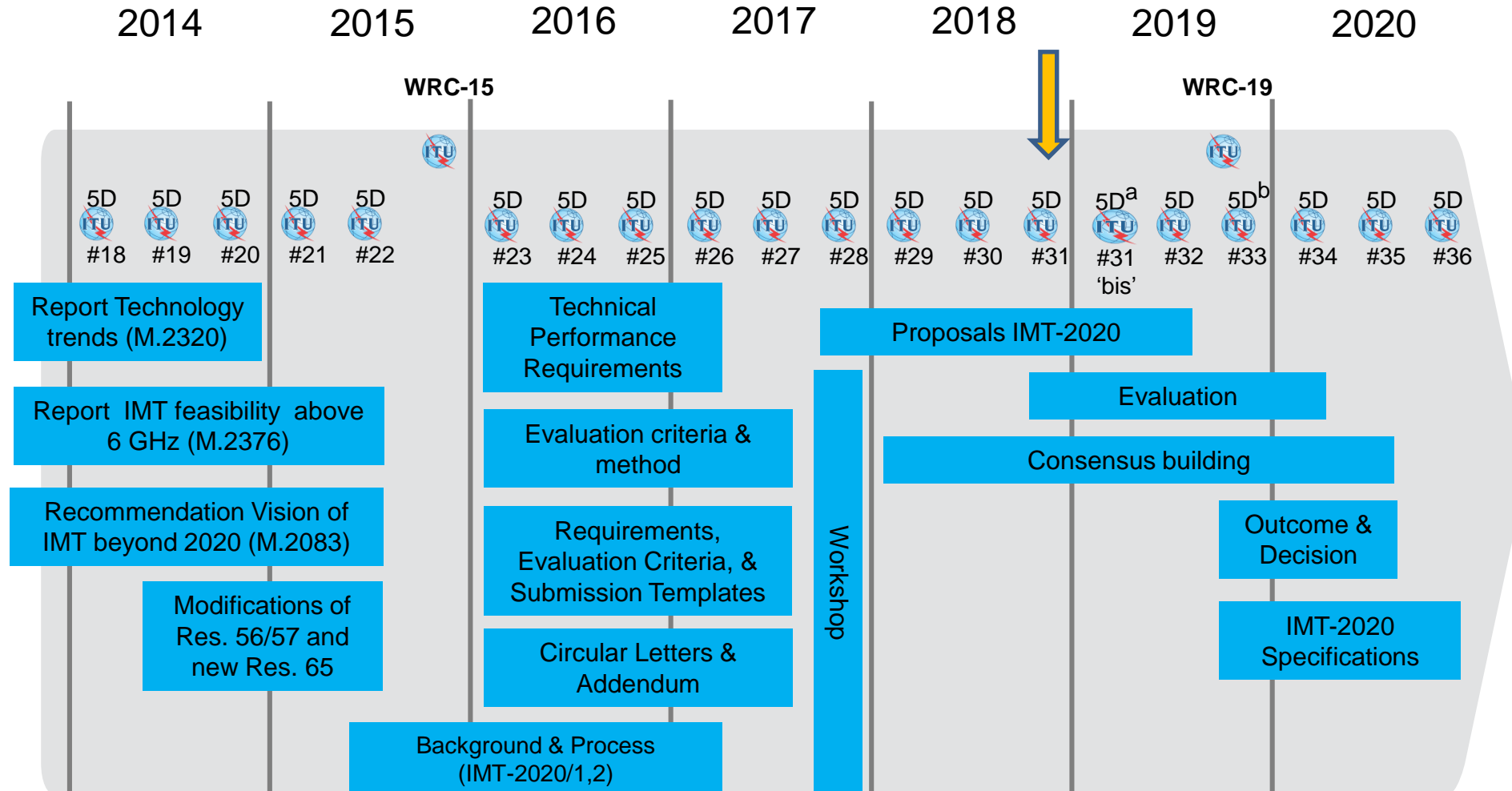
ITU Perspective – IMT 2020 (continued)

- February 2017 – ITU completed a cycle of studies on the key performance requirements of 5G technologies for IMT-2020
- November 2017 – adopted Report [ITU-R M.2410](#), “Minimum requirements related to technical performance for IMT-2020 radio interface(s)”
 - describes those key requirements for the minimum technical performance of IMT-2020 candidate *radio interface technologies*
- Candidate radio technologies – including 3GPP NR and a combination of LTE +NR - *will be evaluated* against these performance requirements utilizing [Report ITU-R M.2412](#), (Nov 2017) “Guidelines for evaluation of radio interface technologies for IMT-2020”, which establishes defined evaluation criteria & scenarios
 - See next slides for timelines
- **Those meeting the requirements and the evaluation guidelines will be an “IMT-2020” technology.**



M.2083-03

Detailed Timeline & Process For IMT-2020 in ITU-R




(a) – five day meeting, (b) – focus meeting on Evaluation (Technology)

KEY ITU-R IMT-2020 Documents for the Evaluation (Technology Submission Focus)

(Source WP 5D)

- [Document IMT-2020/2 Rev1](#) – “Submission, evaluation process and consensus building for IMT-2020”
- [Report ITU-R M.2410](#) – “Minimum requirements related to technical performance for IMT-2020 radio interface(s)”
- [Report ITU-R M.2411](#) – “Requirements, evaluation criteria and submission templates for the development of IMT-2020”
- [Report ITU-R M.2412](#) – “Guidelines for evaluation of radio interface technologies for IMT-2020”

Comparison of IMT Technology Developments in ITU-R

ITEM 	IMT-2000	IMT-Advanced	IMT-2020
VISION	M.687 & M.816	M.1645	M.2083
Year	1992	2003	2015
Pages	29	24	19
REQUIREMENTS	M.1034	M.2134	M.2410
Year	1997	2008	2017
Pages	28	8	9
SUBMISSION	8/LCCE/47 + Add	M.2133	M.2411
Year	1998	2008	2017
Pages	10	29	28
EVALUATION	M.1225	M.2135	M.2412
Year	1997	2009	2017
Pages	61	70	137
SPECIFICATIONS	<i>M.1457-0</i>	<i>M.2012-0</i>	<i>M.[IMT-2020.SPECS]</i>
Year	2000	2012	Anticipated published 2020
Current Version	<i>M.1457-13</i>	<i>M.2012-3</i>	-
Year	2017	Published early 2018	

Future Planned Meeting Dates for Working Party 5D Following WRC-15.

Please check the ITU website in case meeting details have changed (<http://www.itu.int/events/monthlyagenda.asp?lang=en>).

GROUP	No.	FROM	TO	PLACE
WP 5D	23	23 February 16	2 March 16	China
WP 5D	24	14 June 16	22 June 16	Geneva
WP 5D	25	5 October 16	13 October 16	Geneva
WP 5D	26	14 February 17	22 February 17	Geneva
WP 5D	27	13 June 17	21 June 17	Canada
WP 5D	28	3 October 17	11 October 17	Germany
WP 5D	29	31 January 18	7 February 18	Korea
WP 5D	30	13 June 18	20 June 18	Mexico
WP 5D	31	9 October 18	16 October 18	Japan
WP 5D	31bis	11 February 19	15 February 19	Geneva
CPM19-2	—	18 February 19	28 February 19	Geneva
WP 5D	32	9 July 19	17 July 19	[Geneva]
SG 5	—	2 September 19	3 September 19	Geneva
RA-19	—	21 October 19	25 October 19	Egypt
WRC-19	—	28 October 19	22 November 19	Egypt
WP 5D	33	[9 December] 19	[13 December] 19	[Geneva]
WP 5D	34	19 February 20	26 February 20	[TBD]
WP 5D	35	24 June 20	1 July 20	[TBD]
WP 5D	36	7 October 20	14 October 20	[TBD]
SG 5	—	23 November 20	24 November 20	Geneva

WP 5D Workshop on IMT-2020 Terrestrial Radio Interfaces Evaluation

- WP 5D intends to have a workshop for IMT-2020 focusing on the evaluation of the candidate terrestrial radio interfaces in conjunction with its 32nd meeting in July 2019, **with presentations from the proponents**, IEGs, and the WP 5D experts. This will facilitate the IEGs to understand the details of the proposed candidate technologies, and to interact with WP 5D and others participating in the ITU-R evaluation process on IMT-2020.
- Information about the workshop will be appropriately communicated and/or updated on the WP 5D webpage <https://www.itu.int/en/ITU-R/study-groups/rsg5/rwp5d/Pages/default.aspx>

IMT-2020 'In-Progress' Candidate Radio Interface Technology "Initial Submissions" to WP 5D as of Meeting #31 October 2018

SUBMITTED PROPOSALS FOR IMT-2020

'3GPP' IMT-2020/3 (Rev. 2) SRIT: LTE+NR RIT: NR	'KOREA' IMT-2020/4 (Rev. 2) RIT: NR	'CHINA' IMT-2020/5 (Rev. 2) SRIT: LTE+NR RIT: NR	'DECT Forum & ETSI' IMT-2020/5 (Rev. 1) RIT: DECT-2020	'TSDSI' IMT-2020/7 (Rev. 1) SRIT: LTE+NR RIT: NR
------------------------------------------------------------------------------------------------	--------------------------------------------------------------------------	-------------------------------------------------------------------------------------------------	-------------------------------------------------------------------------------------------------	-------------------------------------------------------------------------------------------------

"RIT/SRIT Proponent":

Collectively 3GPP OPs
(ARIB, ATIS, CCSA, ETSI,
TTA, TTC, TSDSI)

Korea

China

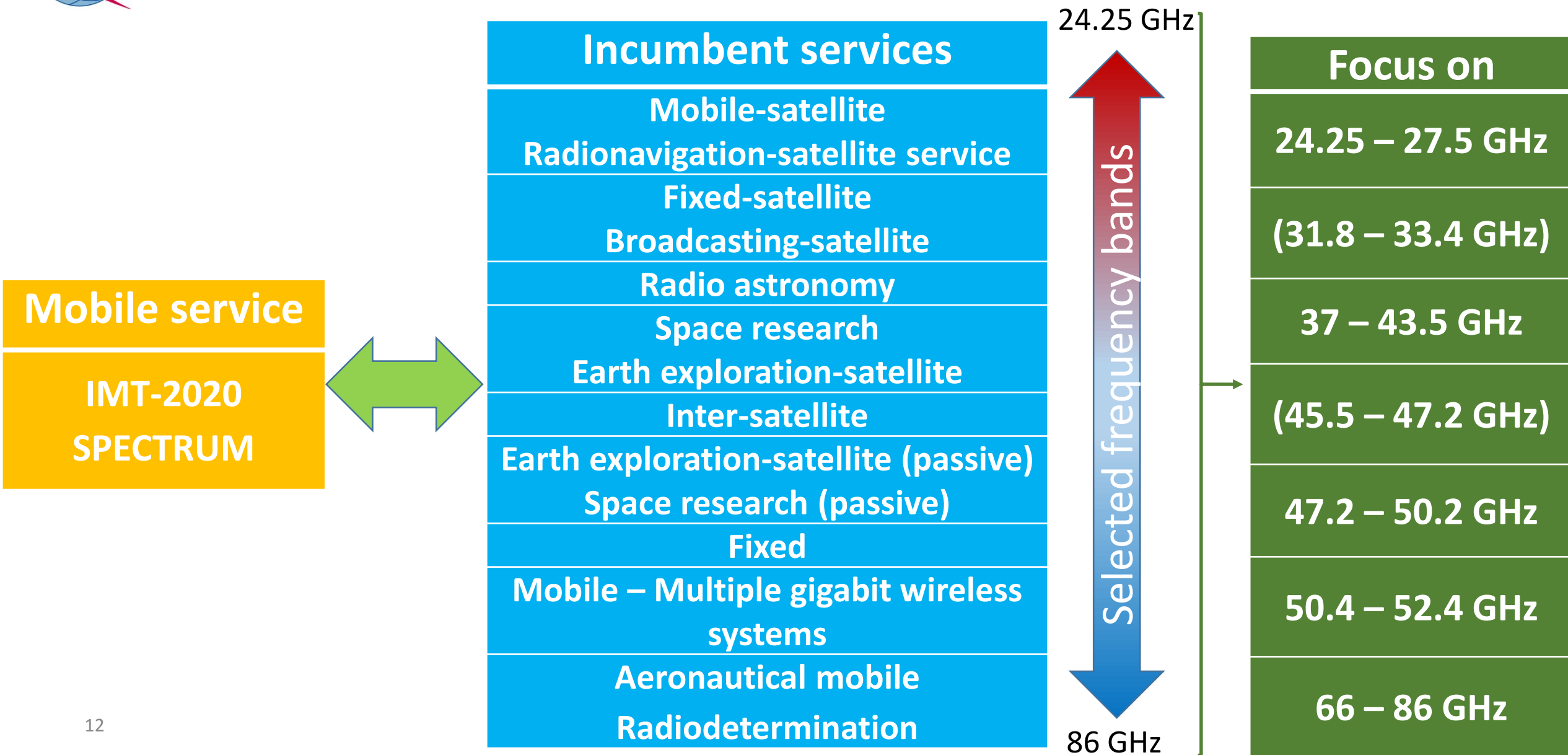
DECT Forum & ETSI

TSDSI

To be available on the ITU website shortly



WRC-19 AI 1.13 sharing & compatibility studies





Conclusions

- **Global collaboration** and joint effort leads to success for IMT-2020 and 5G.
- **ITU-R and industry partnerships** remain strong and well aligned for IMT-2020 and 5G.
- **Engagement by Administrations** is high - both on spectrum and technology.
- **ITU-R IMT-2020 vision** continues as the global target in support of 5G.
- **Initial IMT-2020 candidate radio interface technology submissions** already being received – final submissions due July 2019.
- **The Evaluation process has started!** - advance activities already underway by independent evaluation groups.
- **ITU-R Recommendation on detailed radio interface technology specifications** for IMT-2020 on track for year-end 2020 release.
- ITU-R is well on schedule to implement all necessary procedures to **identify the important future 'mm wave' spectrum (WRC-19)** within the IMT overall spectrum portfolio.

Thank You!

A decorative graphic on the left side of the slide consisting of a series of green circles of varying sizes, arranged in a curved path from the bottom left towards the top right. Each circle contains a white icon: a cloud, a network diagram, a cloud, a binary code "1010", a download arrow, a globe, a padlock, an envelope, and a speech bubble.

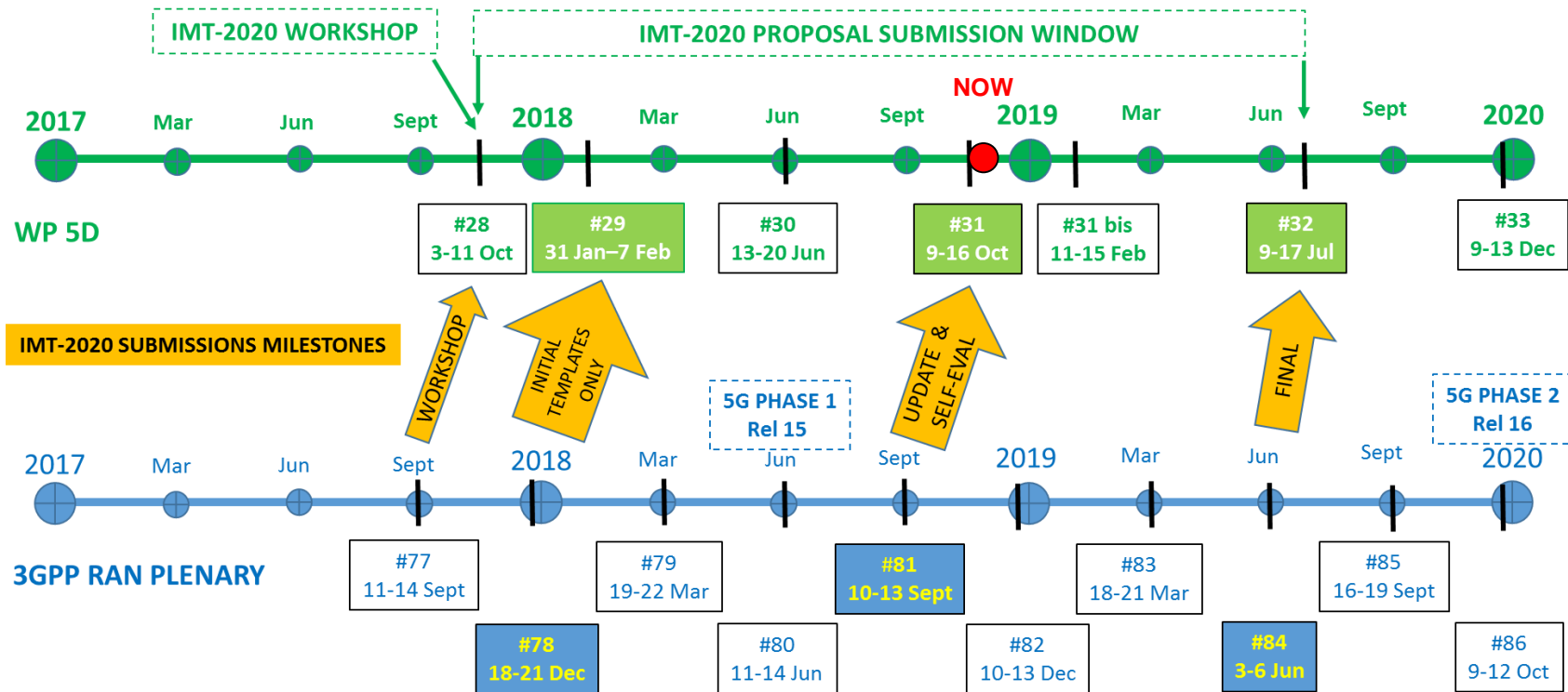
The 3GPP Submission

Source: RAN ITU-R Ad-hoc Convenor

3GPP System

- 📶 3GPP aims to the definition of a full system (Radio and Core Network)
- 📶 3GPP specifications will be labelled “5G” from Release 15 onwards
- 📶 5G requirements
 - Service: TS 22.261 “Service requirements for next generation new services and markets”
 - Radio: TR 38.913 “Study on scenarios and requirements for next generation access technologies”
- 📶 Overall architecture (expected Dec 2017):
 - TS 23.501: “System Architecture for the 5G System; Stage 2”
 - TS 23.502: “Procedures for the 5G System; Stage 2”
- 📶 RAN aspects
 - TR 38.901: “Study on channel model for frequencies from 0.5 to 100 GHz”
 - TR 38.912: “Study on new radio access technology”
 - Technical specifications will be captured in the 36, 37 and 38 series

IMT-2020 submission - timeplan



IMT-2020 submission - timeplan

Submission Milestone Name	3GPP Meeting	ITU-R Meeting	General Submission Content	Submission Templates (Release Basis)	Self- Evaluation (Release Basis)
Workshop	RAN # 77 Sept 2017	WP 5D #28 Oct 2017	Overview	-	-
Initial Templates Only	RAN # 78 Dec 2017	WP 5D # 29 Feb 2018	Description Templates	Description Templates 5.2.3 (R15)	-
Update & Self-Eval	RAN # 81 Sept 2018	WP 5D # 31 Oct 2018	Description Templates Compliance Templates Self-Evaluation	Description Templates 5.2.3 (R15) Compliance Templates 5.2.4 (R15)	Self-Evaluation (R15)
Final	RAN # 84 June 2019	WP 5D # 32 July 2019	Description Templates Compliance Templates Self-Evaluation	Description Templates 5.2.3 (R15+R16) Compliance Templates 5.2.4 (R15+R16)	Self-Evaluation (R15+R16)

IMT-2020 submission format



Submission 1

- SRIT
 - Component RIT: NR (*)
 - Component RIT: EUTRA/LTE
 - incl. standalone LTE, NB-IoT, eMTC, and LTE-NR DC
 - full 38 and 36 series, and subset of 37 series

Submission 2 (In addition to the above)

- NR RIT (*)





Naming

- Name : 5G
- Footnote: Developed by 3GPP as 5G, Release 15 and beyond

(*) The plan is to leverage the NR RIT (in submission 2) as the NR component RIT in submission 1; NR details TBD

Where are we now?

-  3GPP approved an updated submission in October based on 3GPP Release 15
-  This Submission is not final. Therefore, it will be updated on the basis of 3GPP workplan and the Final submission will be delivered according to WP5D timeplan

Preliminary Description Template and Self-Evaluation of 3GPP 5G candidate

- 📶 This document allows the Independent Evaluation Groups to familiarise with the 3GPP 5G solution for IMT-2020 and to prepare the evaluation activity
- 📶 The updated description of 3GPP 5G and initial self evaluation can be found in PCG41_08 and provides
 - characteristics template for SRIT and NR RIT
 - compliance template for SRIT and NR RIT
 - link budget
 - preliminary self evaluation report (TR37.910 V1.0.0)

Thank you!



Overview of RAN aspects

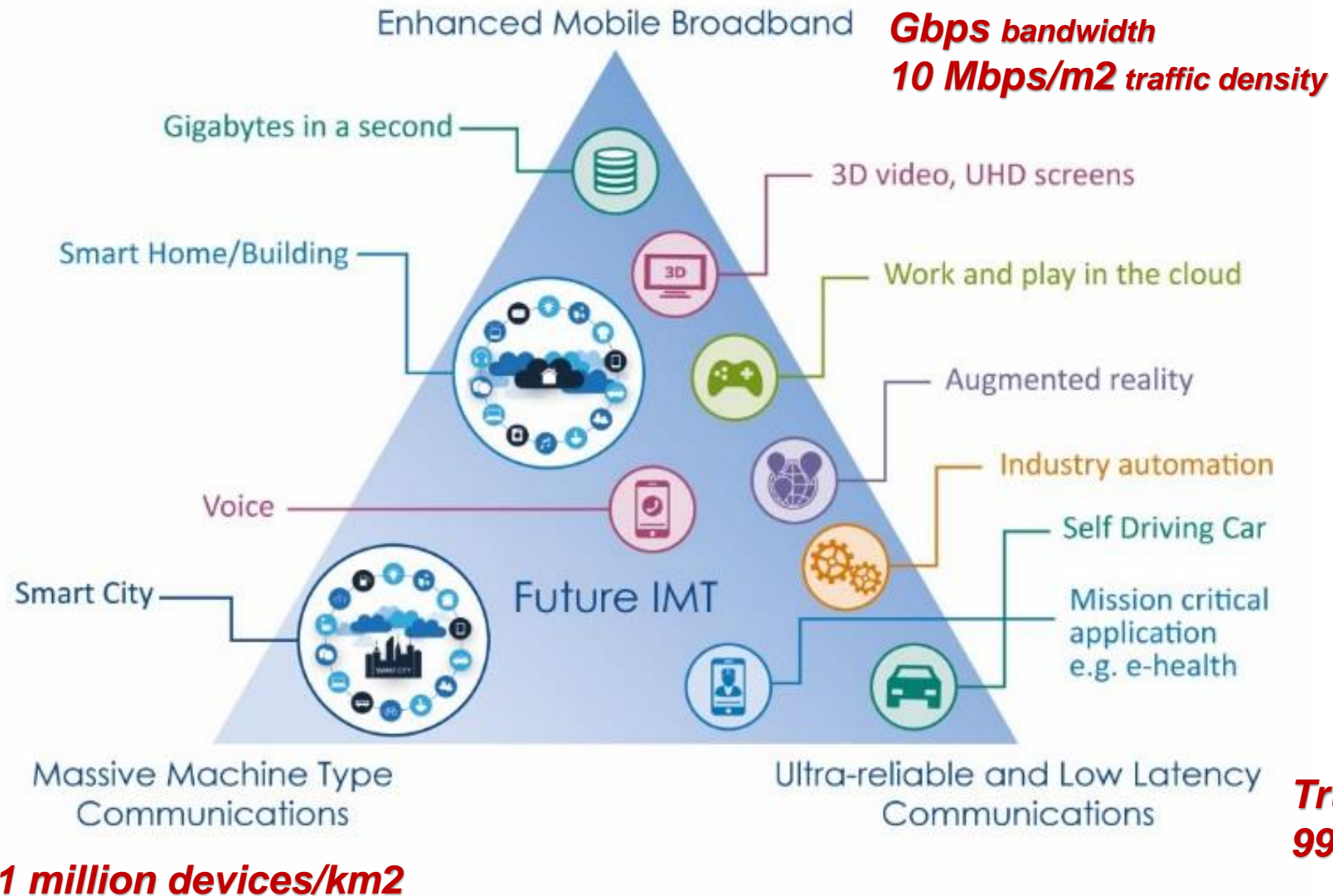
Balazs Bertenyi (Chairman of 3GPP RAN)

Outline



- 5G vision → 5G NR standards
- What is 5G NR
- The advent of 5G – 3GPP Release 15

5G vision - at the outset



5G vision - for real



Perfect storm of multiple technology breakthroughs:

- **Low latency** radio with fully flexible network
- **Artificial Intelligence** and Automation
- **Device revolution** for AR/VR
- **Vertical industries** going wireless



5G vision → 5G NR

What is 5G NR ?

- Operation from low to very high bands: 0.4 – 100GHz
 - Including standalone operation in unlicensed bands
- Ultra wide bandwidth
 - Up to 100MHz in <6GHz
 - Up to 400MHz in >6GHz
- Set of different numerologies for optimal operation in different frequency ranges

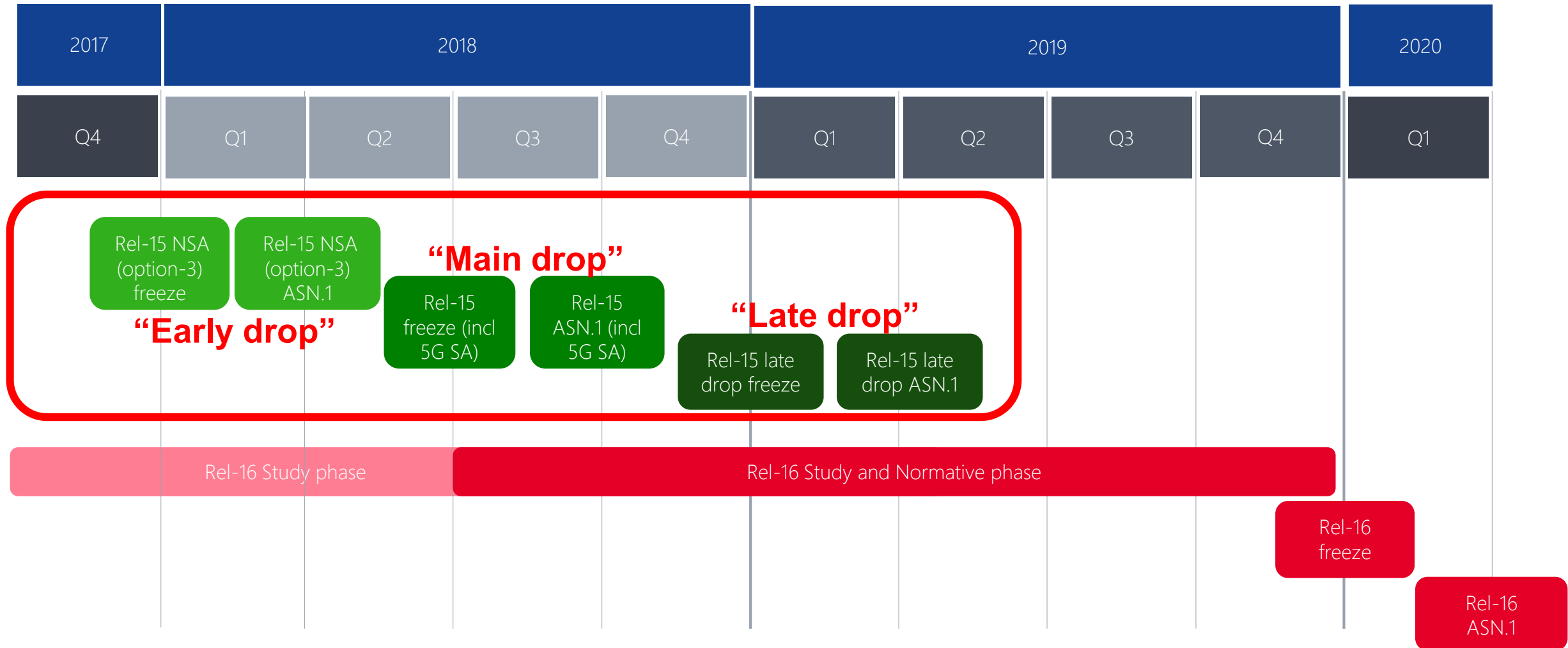
What is 5G NR ?

- Native forward compatibility mechanisms
- New channel coding
 - 📶 LDPC for data channel, Polar coding for control channel
- Native support for Low Latency and Ultra Reliability
- Flexible and modular RAN architecture: split fronthaul, split control- and user-plane
- Native end-to-end support for Network Slicing






Release 15 – the advent of 5G

Timeline



Why the multiple “drops”

“Early drop” for Non-Standalone 5G

-  Addresses the most urgent deployment needs for eMBB
 -  Uses LTE anchor with 5G NR in Dual Connectivity configuration
-  Accelerated specification to ensure a single global ecosystem

“Main drop” for Standalone 5G

-  Contains full standalone 5G support with 5G Core

“Late drop” for accelerated migration

-  Contains specs for all potential migration options



Thank you!

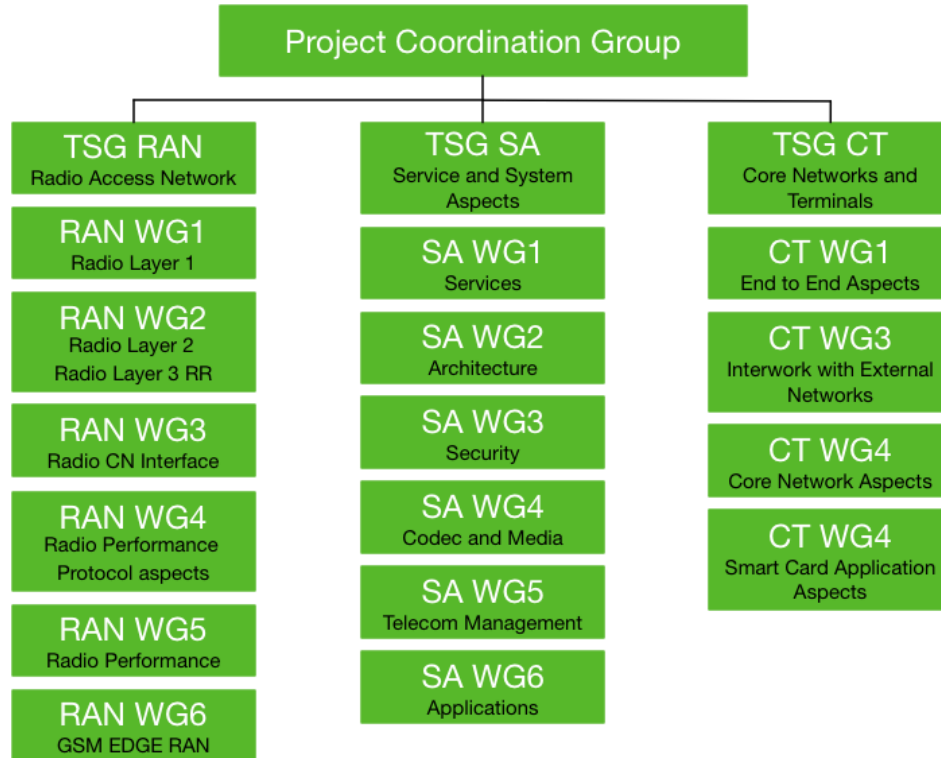


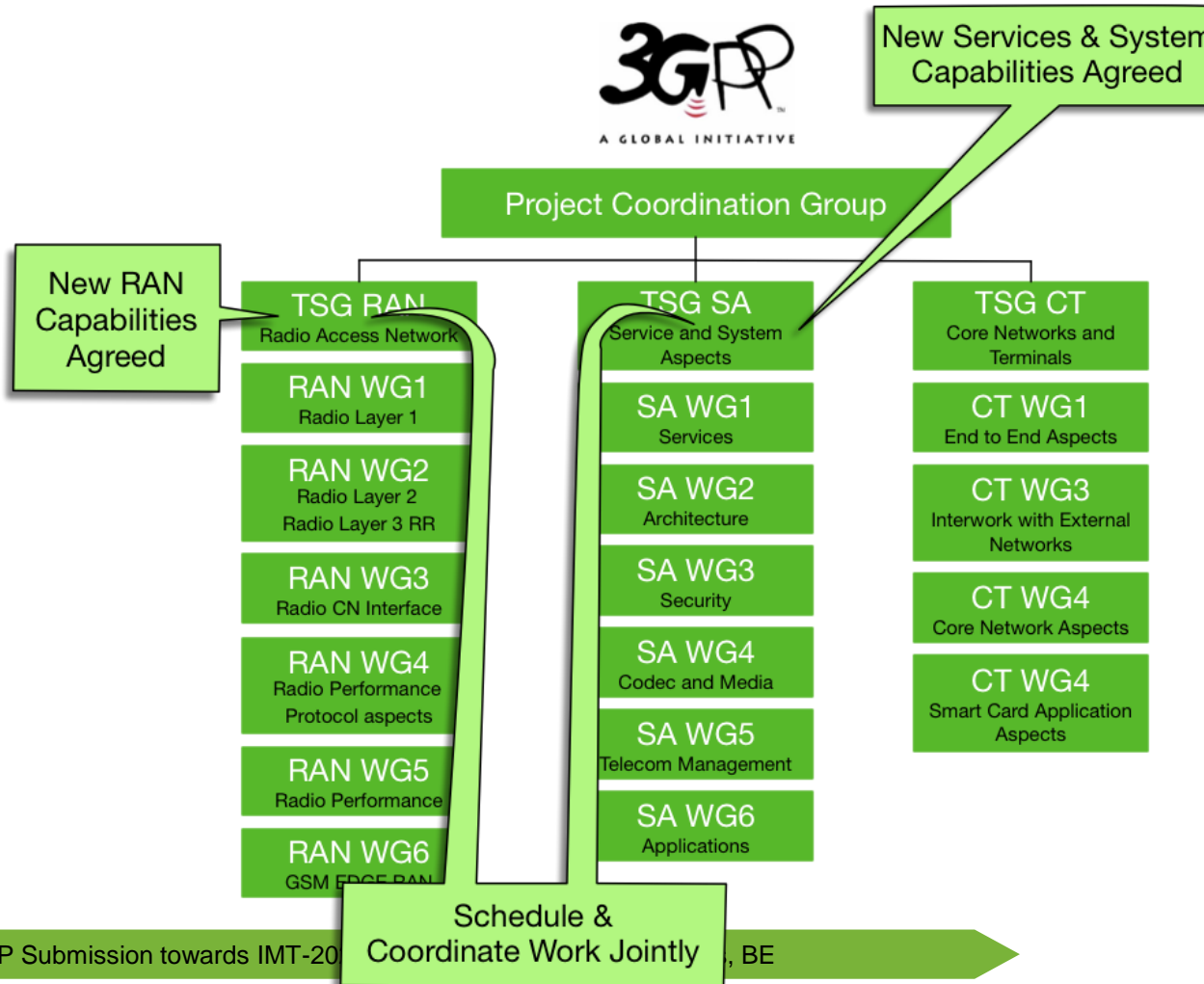
Balazs Bertenyi
Chairman of 3GPP RAN
balazs.bertenyi@nokia.com
+36 20 9849152

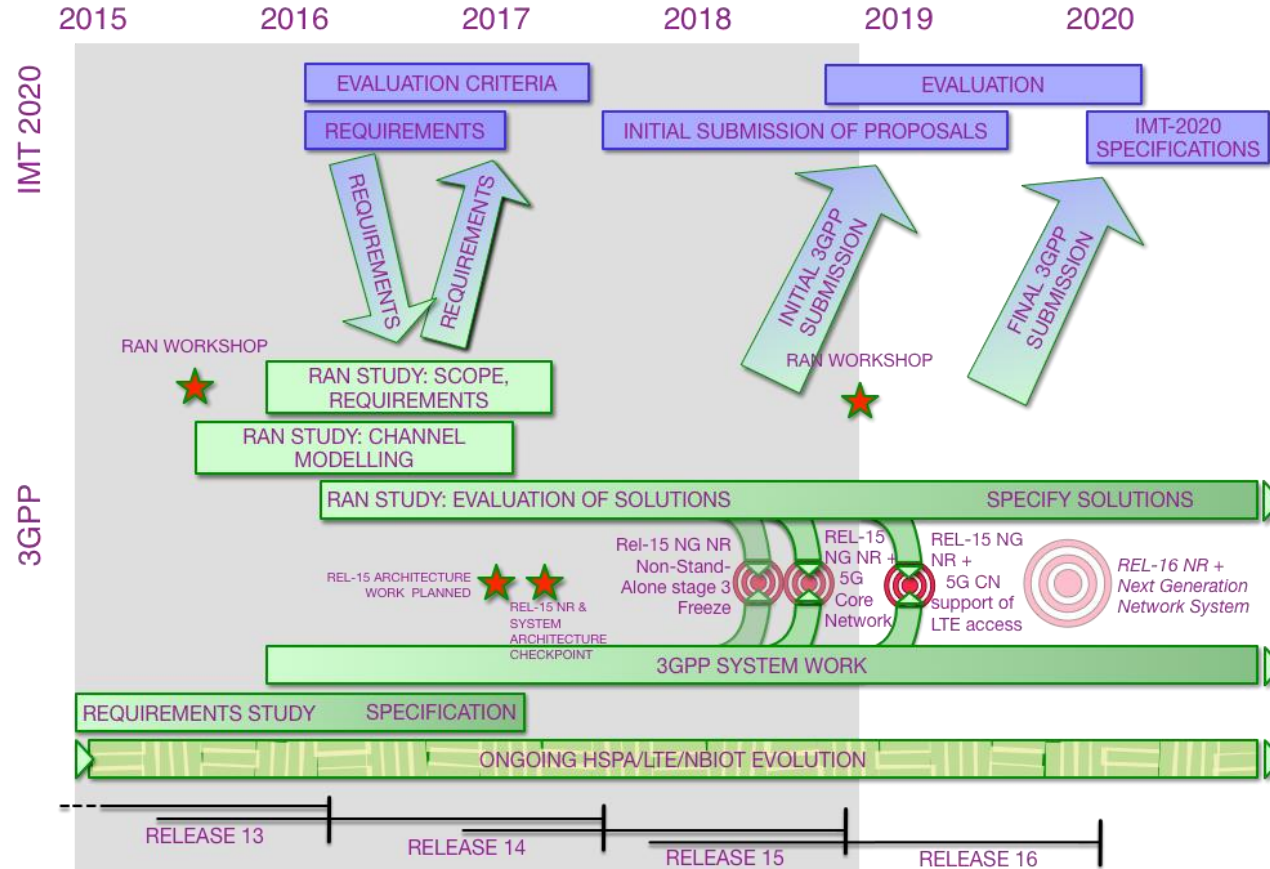


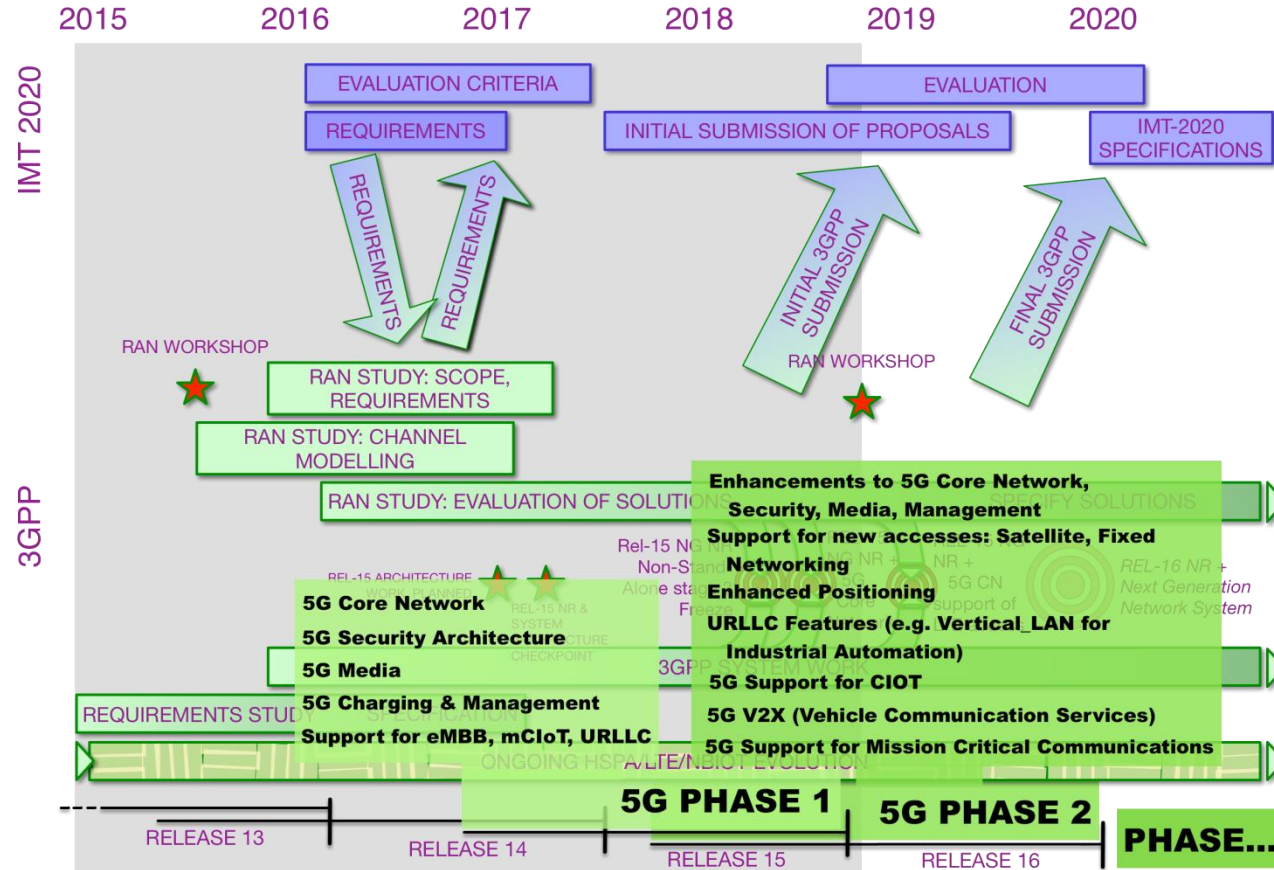
System and Core Network Aspects

Erik Guttman
3GPP TSG SA Chairman
Samsung R&D Institute UK

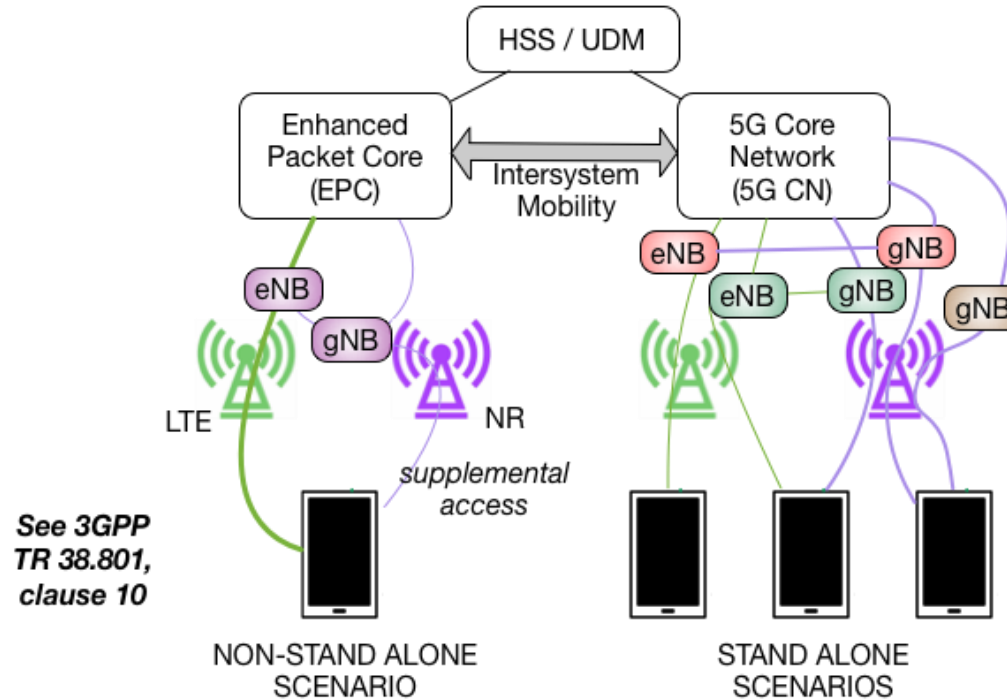






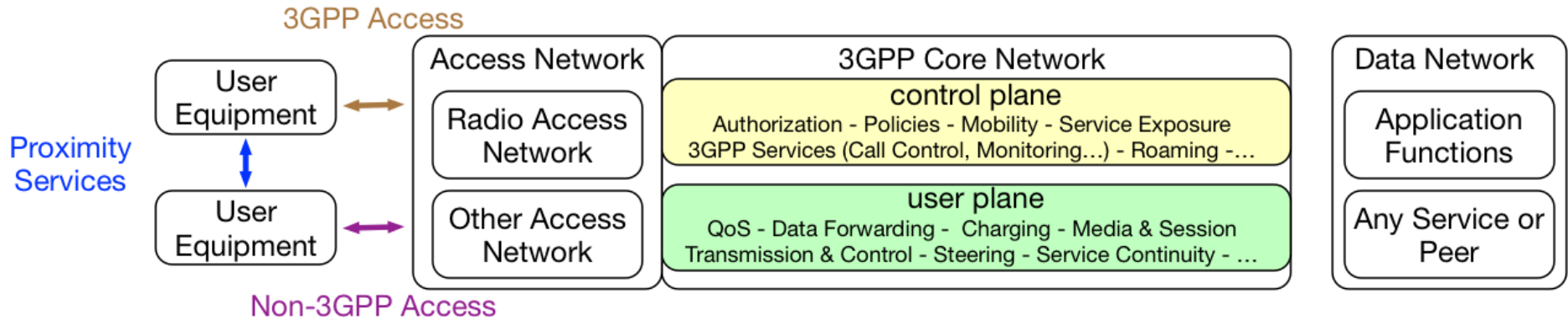


5G Deployment Scenarios



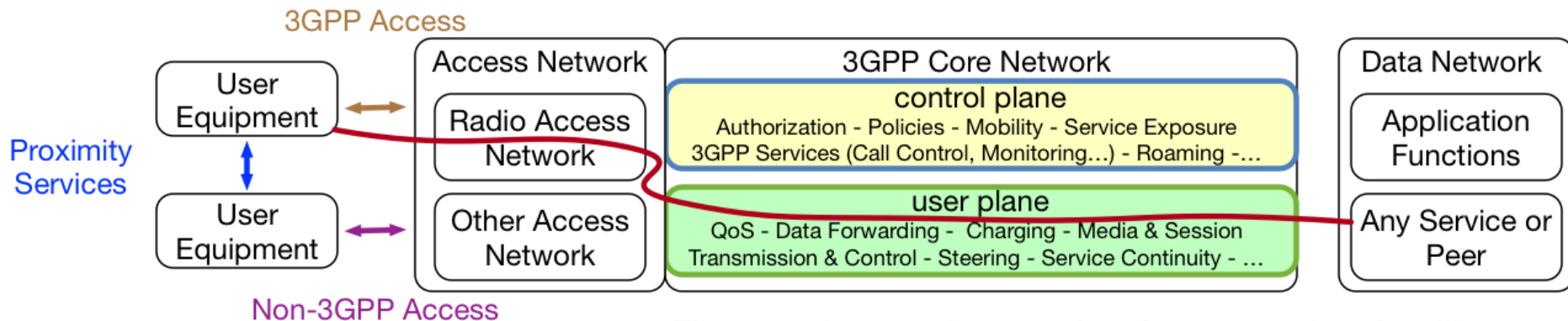
Stage 3 freeze:	12.17	12.18	12.18	06.18
Option [see 38.801]:	3	7	4	2

3GPP System



3GPP System

The control plane enables and controls services.

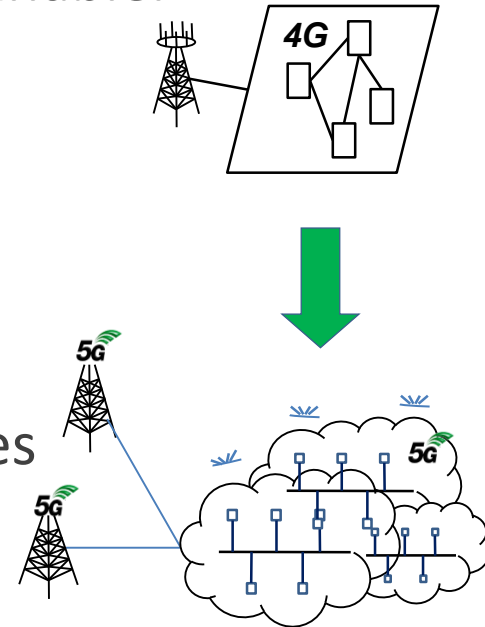


The user plane carries user data & some service signalling.

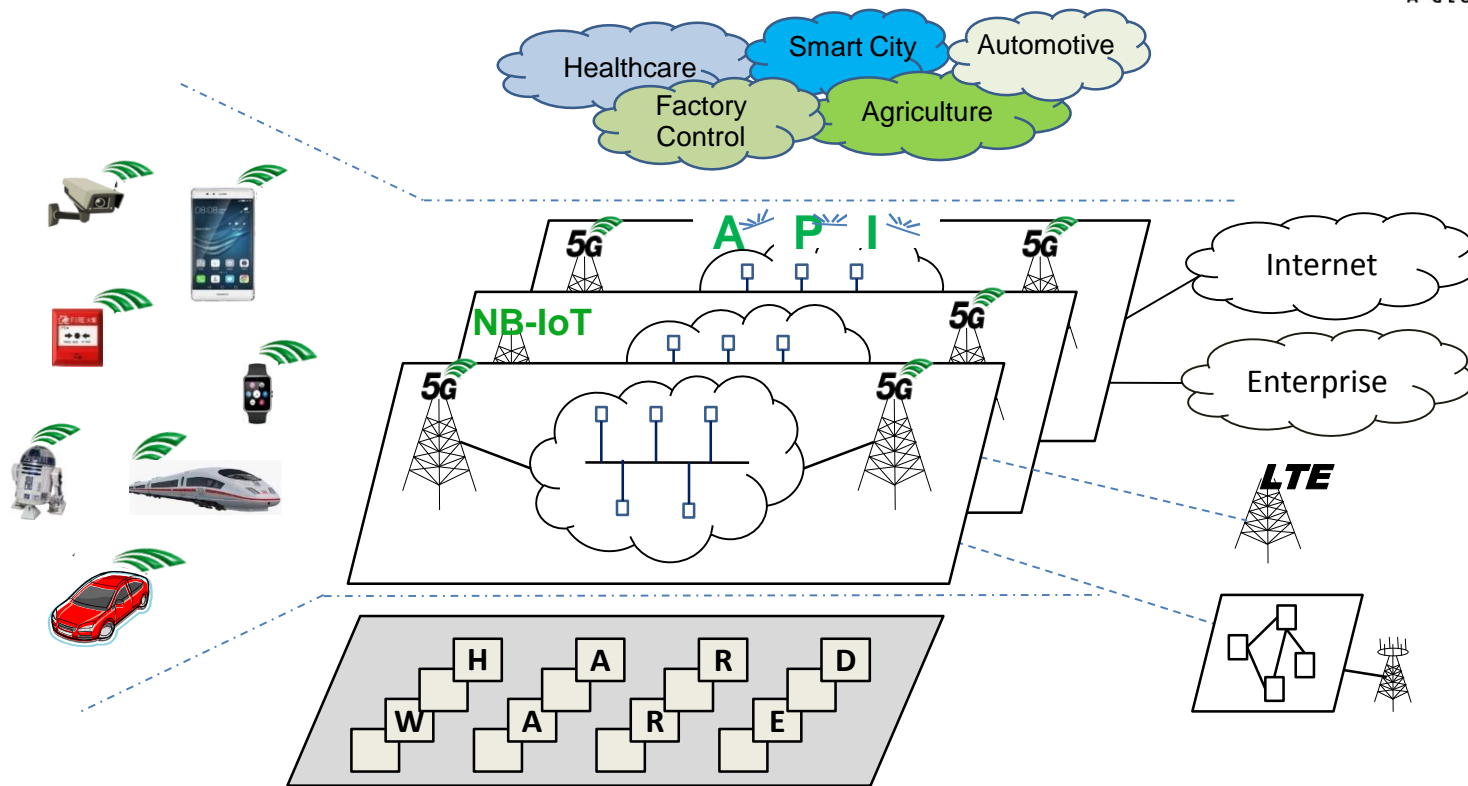
Many services are delivered 'end to end' via the user plane.

Software- and Service-centric Transformation

- One CoreNetwork fits all → Open & Flexible Enabler
- Telecom Operators → Multiple Stakeholders
- Phones → Things
- Procedures → Services
- Static Topology → On-demand Resources
- Dedicated Hardware → Orchestrated Resources
 - Network Function → Virtualization
 - Single Network → Slice



5G System Service Perspective

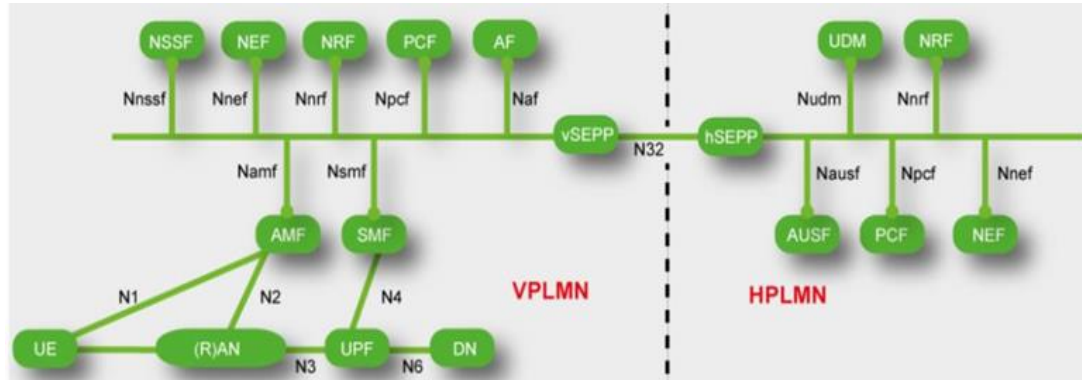


5G Core Technologies

- 📶 **Orchestration and Virtualization (NFV)** – de-couple logical function from hardware
- 📶 **Slicing** – logical end-2-end networks tailed to customer needs
- 📶 **Edge Computing (MEC)** – resources where they are needed (URLLC)
- 📶 **Exposure (API)** – 3rd party access to 5G services
- 📶 **Service Based Architecture (SBA)** – stateless, open, flexible
- 📶 **Harmonized Protocols & Access Agnostic** – generic solutions

Control Plane Feature – Service Based Architecture









- 📶 Each NF as a combination of mono-functional NF services.
 - NFs provide and consume services to and from each other using a unified protocol.
 - Stateless NF was specified for AMF.
- 📶 In Rel-16 NF service granularity will diminish and more NFs will become stateless.





Ultra-reliable and Low Latency Communications



<p>Broadband access in dense areas</p> <p>PERVASIVE VIDEO</p> 	<p>Broadband access everywhere</p> <p>50+ MBPS EVERYWHERE</p> 	<p>Higher user mobility</p> <p>HIGH SPEED TRAIN</p> 	<p>Massive Internet of Things</p> <p>SENSOR NETWORKS</p> 
<p>Extreme real-time communications</p> <p>TACTILE INTERNET</p> 	<p>Lifeline communications</p> <p>NATURAL DISASTER</p> 	<p>Ultra-reliable communications</p> <p>E-HEALTH SERVICES</p> 	<p>Broadcast-like services</p> <p>BROADCAST SERVICES</p> 

- Address demands and business contexts of 2020 and beyond.
- Enable a fully mobile and connected society.
- Empower socio-economic transformations in countless ways.

Enhanced Mobile Broadband

Use Cases



Higher Data Rates



Higher User Mobility



Highly variable data rates



Diverse Deployments



Improved Coverage

Overall Goals

- **Enable new business**
- **Greater Efficiency (lower cost per bit for capital investment, operations & energy)**
- **Flexibility (not one-size fits all system)**

Enhanced Mobile Broadband

Use Cases



Higher Data Rates



Virtual Reality



Augmented Reality



Tactile Internet



Higher User Mobility



Highly variable data rates



Diverse Deployments



Improved Coverage

Enhanced Mobile Broadband

Use Cases



Higher Data Rates



Higher User Mobility



Pedestrian



Automotive / Urban



High Speed



Highly variable data rates



Diverse Deployments



Improved Coverage

Enhanced Mobile Broadband

Use Cases



Higher Data Rates



Higher User Mobility



Highly variable data rates



IoT Sensors (Low)



New Media (Very High)



Diverse Deployments



Improved Coverage

Enhanced Mobile Broadband

Use Cases



Higher Data Rates



Higher User Mobility



Highly variable data rates



Diverse Deployments



Interior



Urban



Remote Areas



Improved Coverage

Enhanced Mobile Broadband

Use Cases



Higher Data Rates



Higher User Mobility



Highly variable data rates



Diverse Deployments



Improved Coverage



Interior



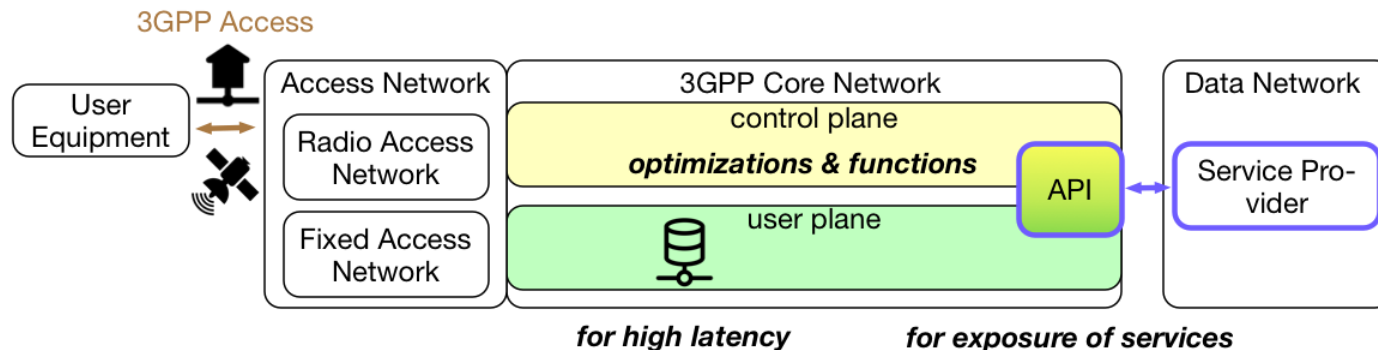
Urban



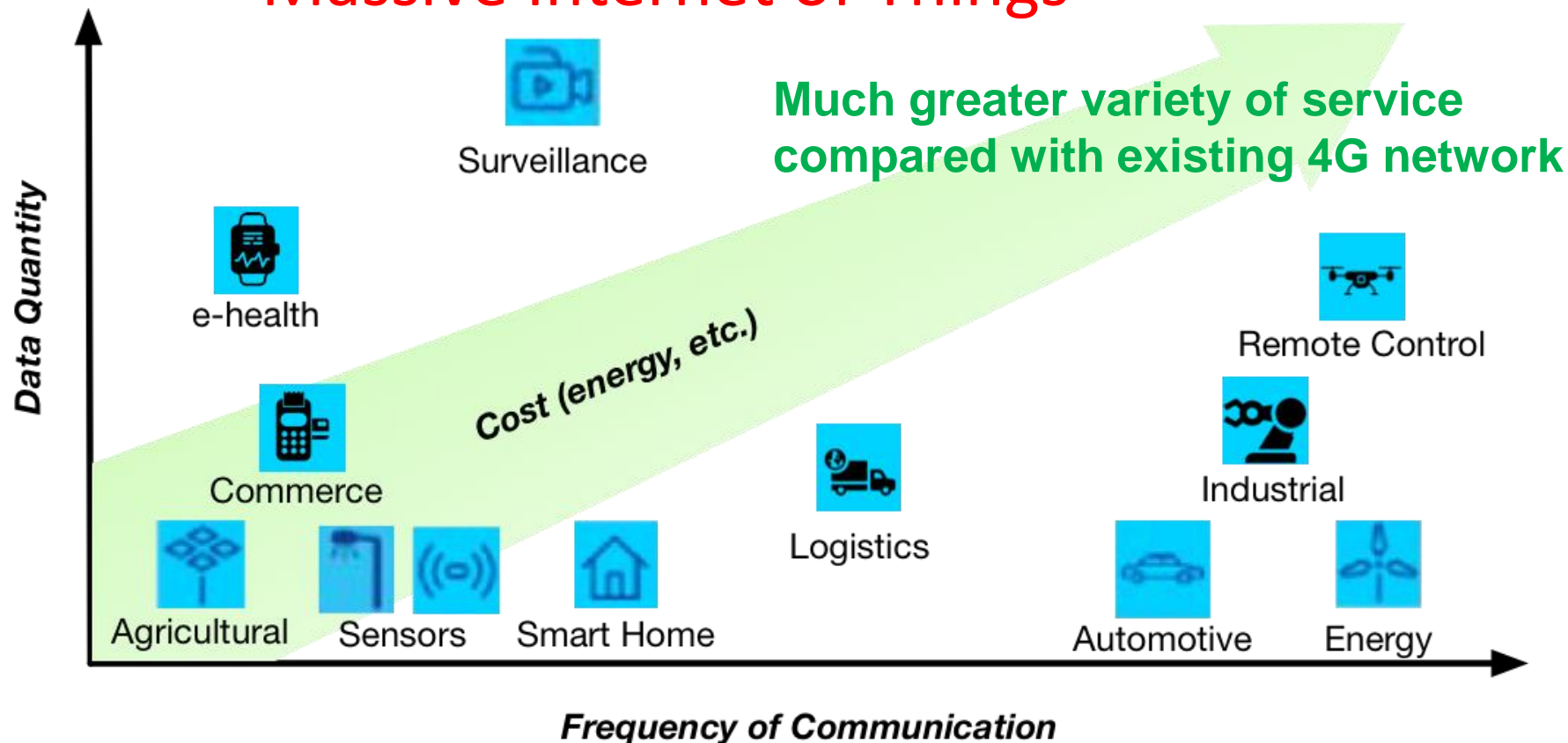
Remote Areas

Enablers of 5G eMBB

- Specific enhancements of the user plane
 - Small / infrequent data communication, high latency communication, power savings mode...
 - Exposure Functions, APIs, Common API Framework – to enable external interworking with 3GPP.
- Support for diverse deployments, improved coverage
 - Control and operation support small cell deployments
 - New 3GPP accesses: wire line-wireless convergence, satellite access
- Improved QoS model: Packet flows & related policies



Massive Internet of Things



Massive Internet of Things

Enablers of mIoT



Network virtualization and Orchestration

- Network automation enables MNO to provide NW services much faster than existing system
->TTM for customers
- NFV enables OPEX reduction by network automation
->Enables automated service with selected NW functions based on SLA (with NW slicing)

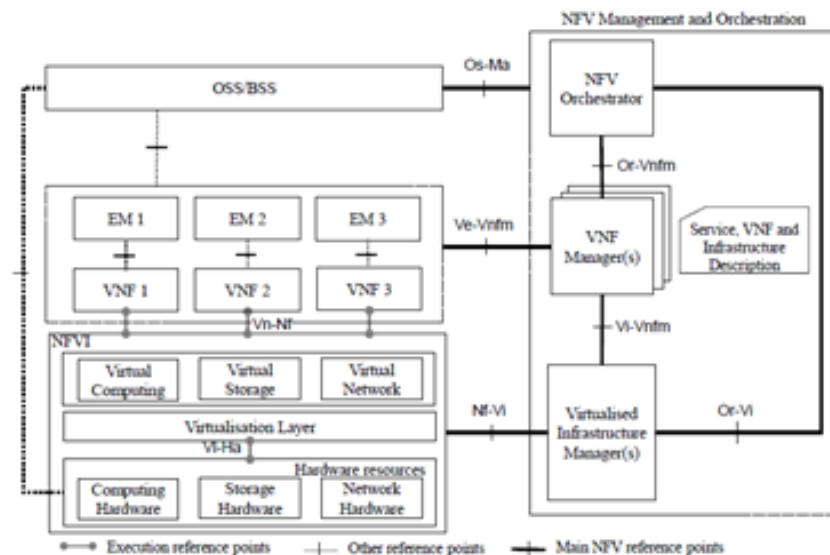


Figure 4: NFV reference architectural framework

Source: ETSI GS NFV 002 V1.2.1

Ultra-reliable and Low Latency Communications

 Examples of Use cases to be covered by 3GPP 5G system

Ultra-reliable

- Factory of the future
- eHealth
- Building automation
- Connected car
- Smart city
- Electrical power distribution
- Rail-bound mass transit

Low Latency

- Factory of the future
- eHealth
- Building automation
- Connected car
- Smart city
- AR/VR
- Program Making and Special Events

Both aspects are critical for a lot of use cases.

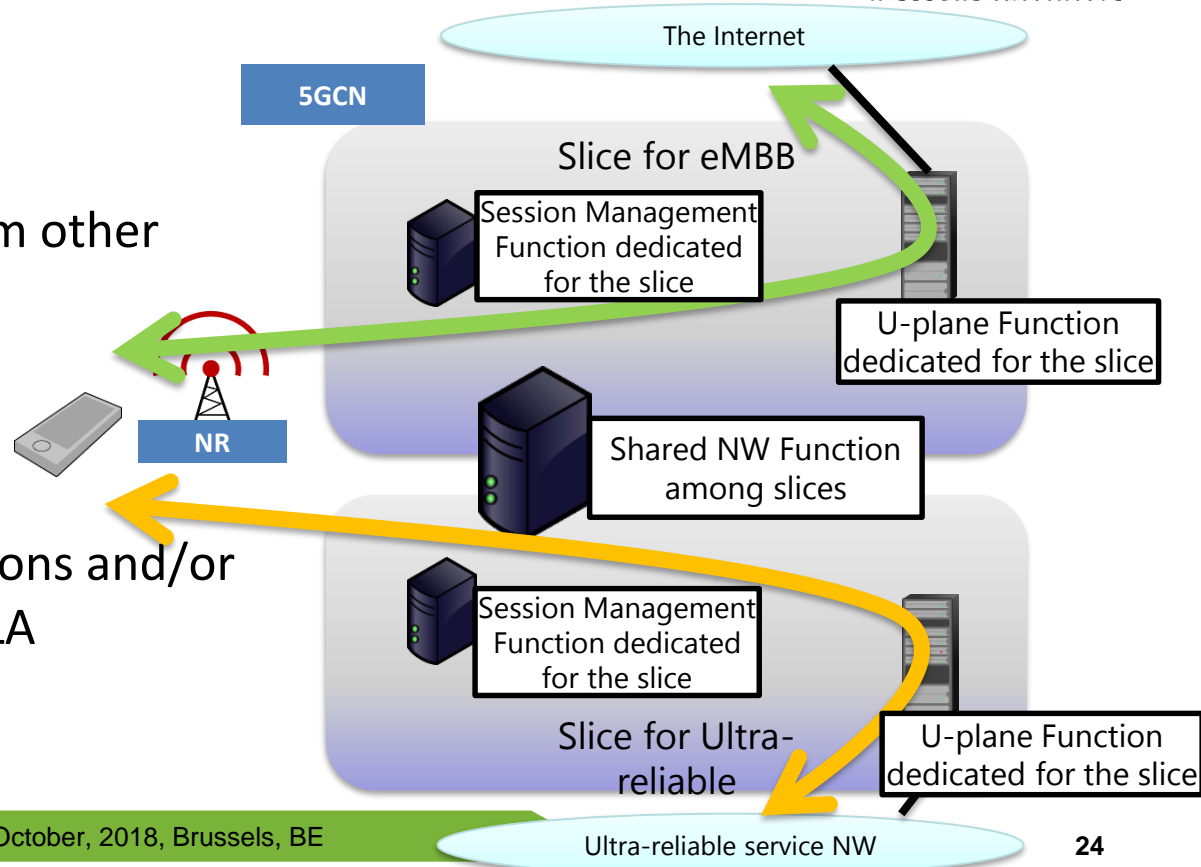
Ultra-reliable and Low Latency Communications

Enablers of URLLC



Network slicing

- Resource isolation from other service
->No service impact caused by other slices failure
- Customized NW functions and/or capacities to ensure SLA

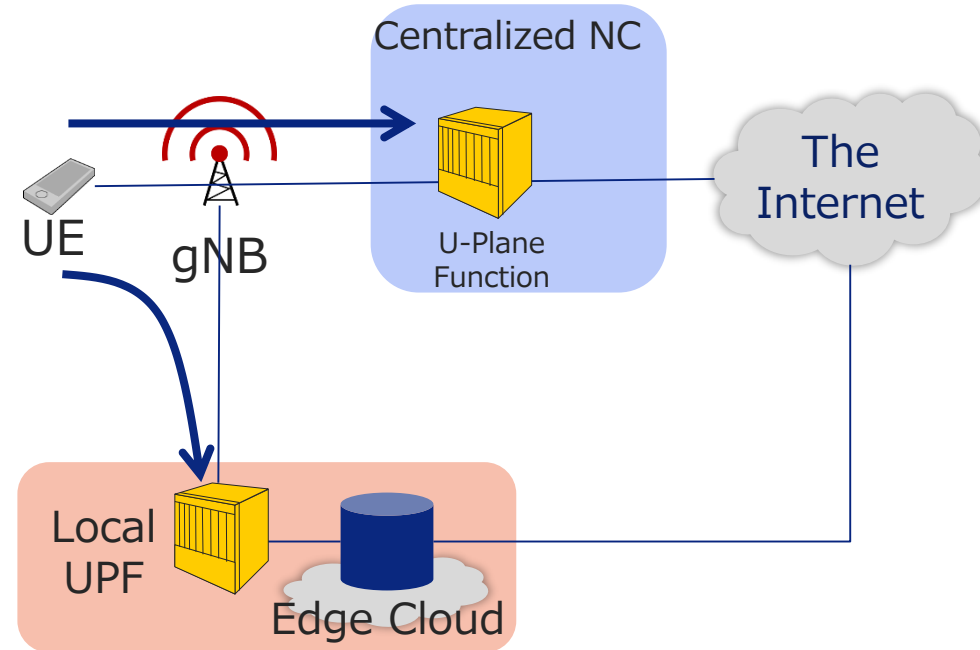


Ultra-reliable and Low Latency Communications

Enablers of URLLC

Edge Computing

- Applications can be hosted at “Edge-side”
->Low Latency compared with centralized manner



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www.3gpp.org

Search for WIDs at <http://www.3gpp.org/specifications/work-plan> and http://www.3gpp.org/ftp/Information/WORK_PLAN/ (See excel sheet)

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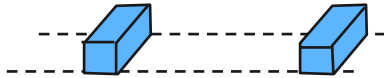


NR Physical Layer Design: Physical layer structure, numerology and frame structure

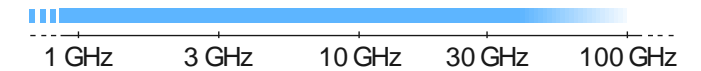
Havish Koorapaty
3GPP TSG RAN WG1 vice-chairman (Ericsson)

NR – Key benefits

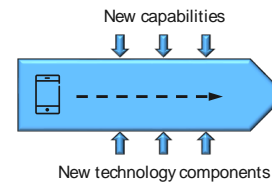
Ultra-lean



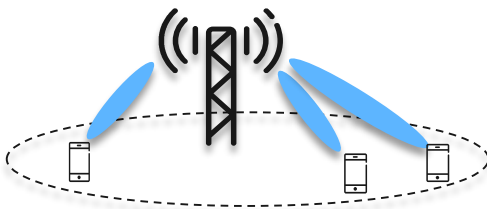
Wide spectrum range



Forward compatibility



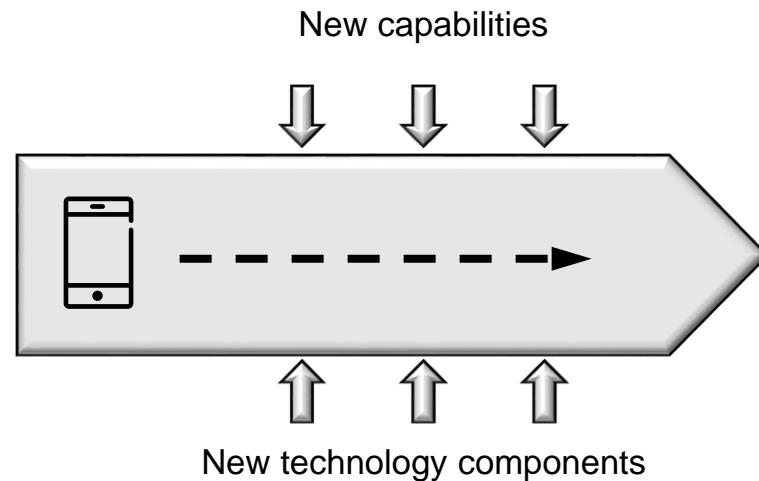
Multi-antenna



Low latency

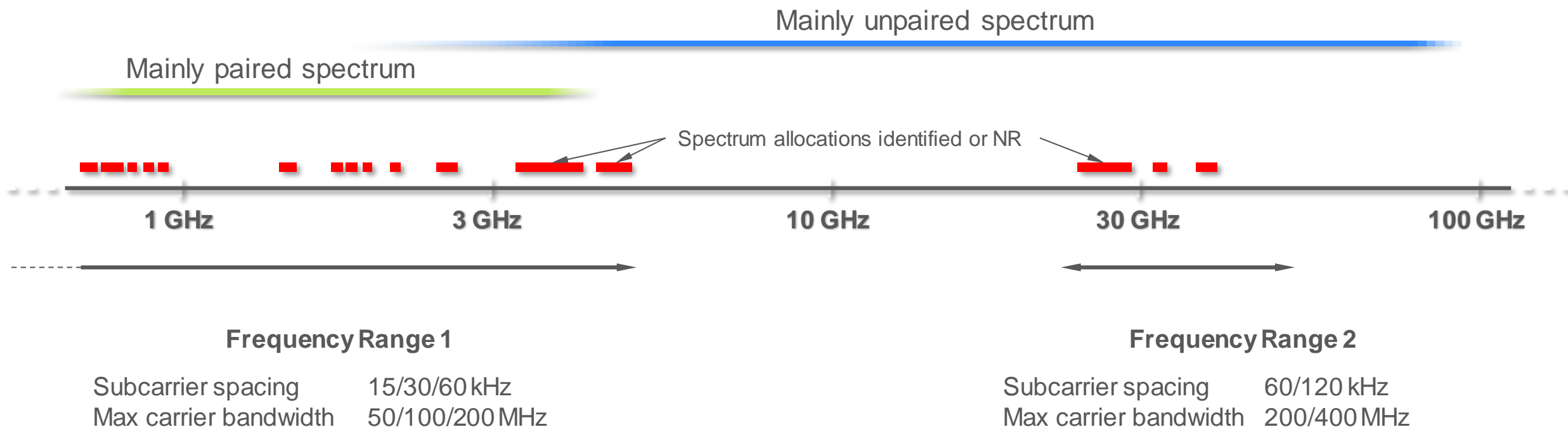


Forward compatibility



- Minimize “always-on” transmissions (ultra-lean)
 - Bad example: Always-on CRS
- Keep transmissions together in frequency
 - Bad example: LTE PDCCH/PCFICH/PHICH
- Avoid static/strict timing relations
 - Bad example: LTE uplink HARQ
- Reserved resources
 - Downlink transmissions rate matched around

Frequency bands



Time-frequency structure

Frame structure

Single frame structure

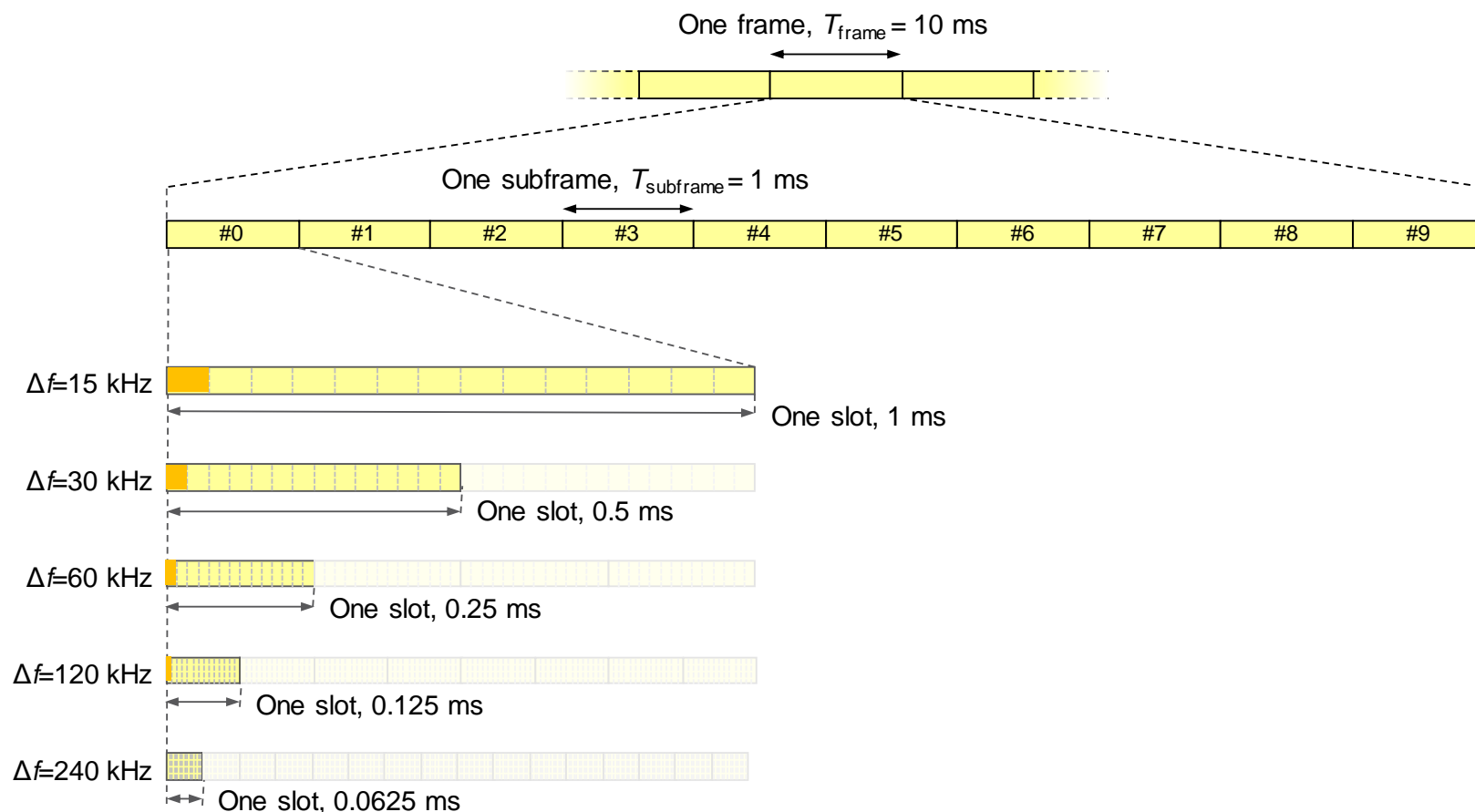
Applicable to FDD and TDD

Dynamic TDD baseline

Possible to semi-statically configure UL/DL split

15 kHz slot identical to LTE subframe

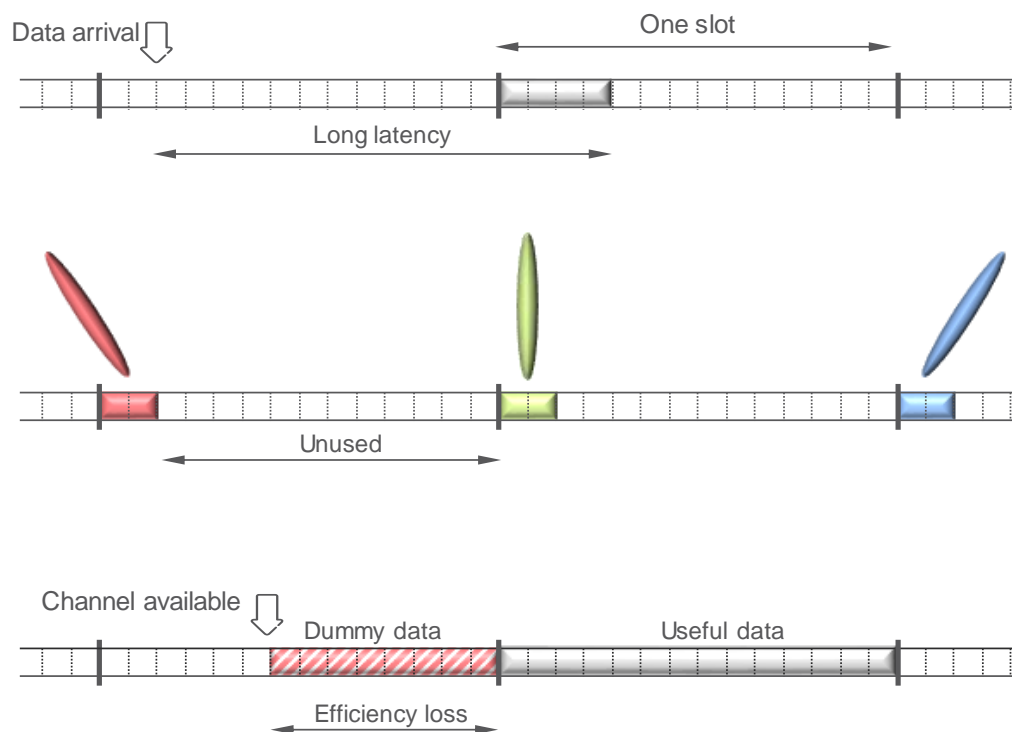
Including extra samples in every 7th symbol



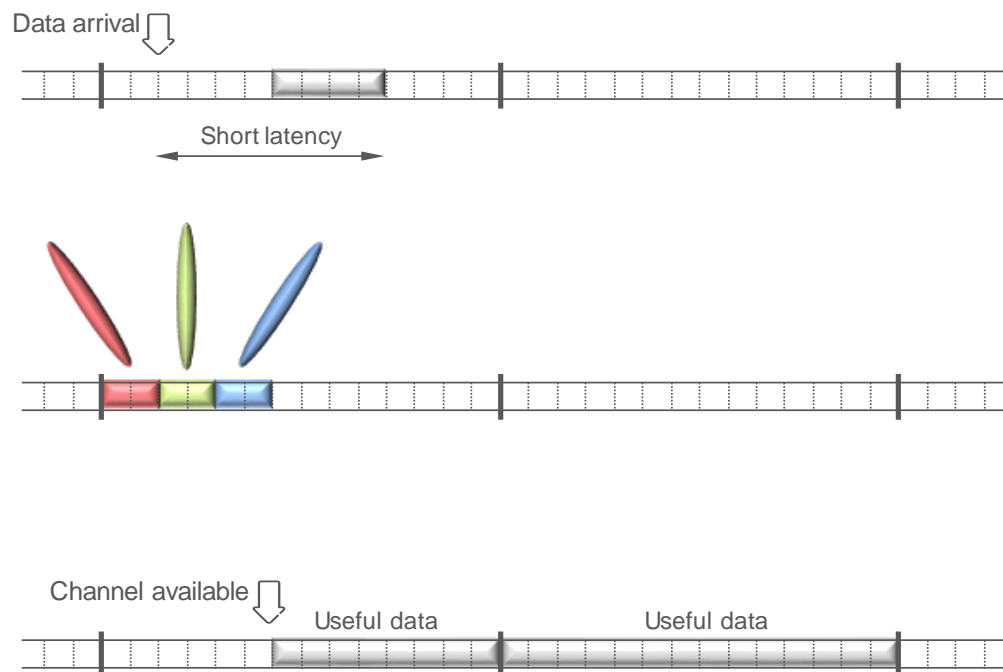
Frame structure

Transmissions not restricted to slot boundaries

Transmissions restricted to slot boundaries

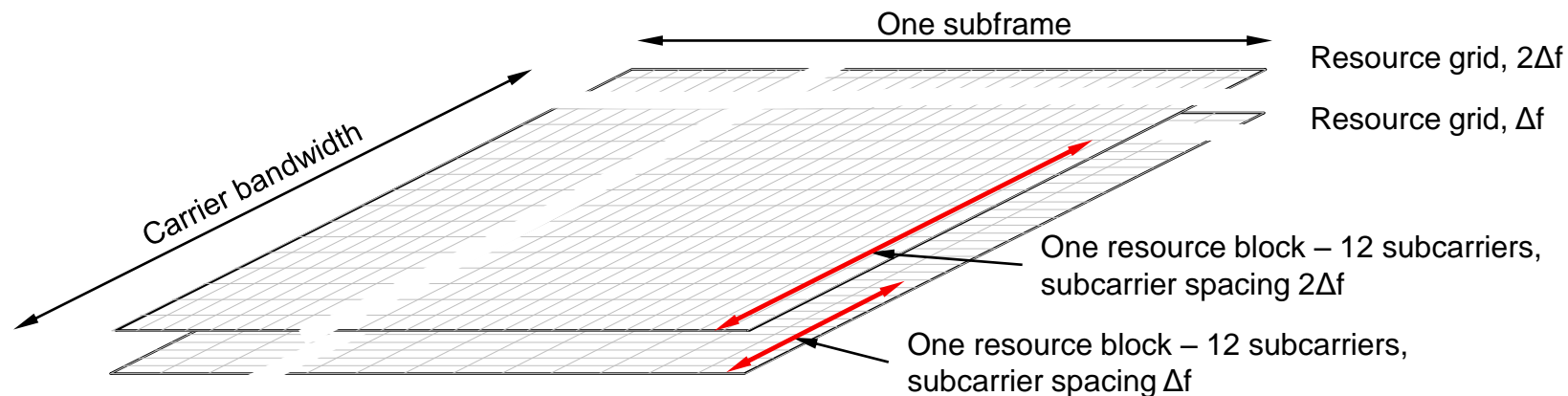


Transmissions **not** restricted to slot boundaries

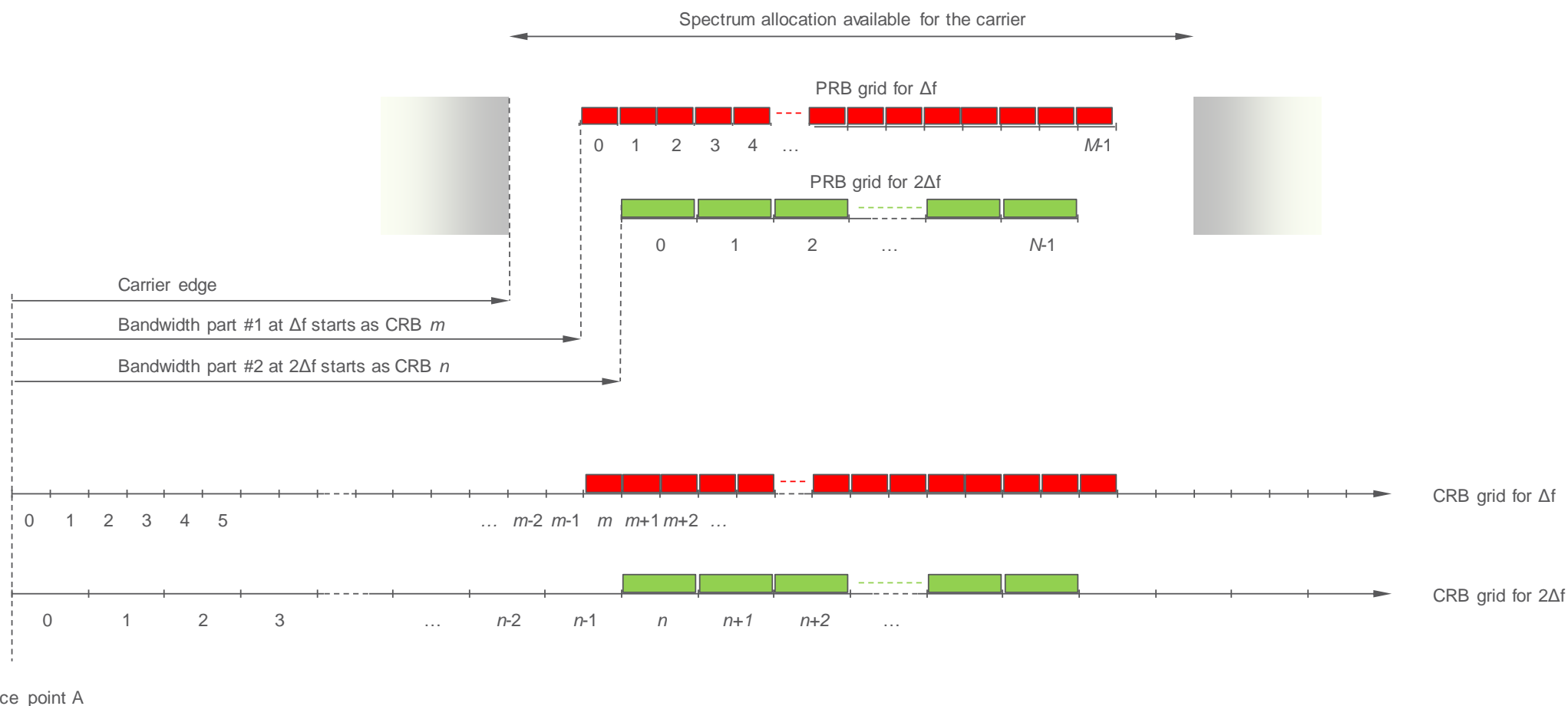


Resource grid

- One resource grid per numerology and antenna port
- Resource block = 12 subcarriers
 - 📶 One dimensional unit (unlike LTE)
- Resource element = 1 subcarrier in one OFDM symbol



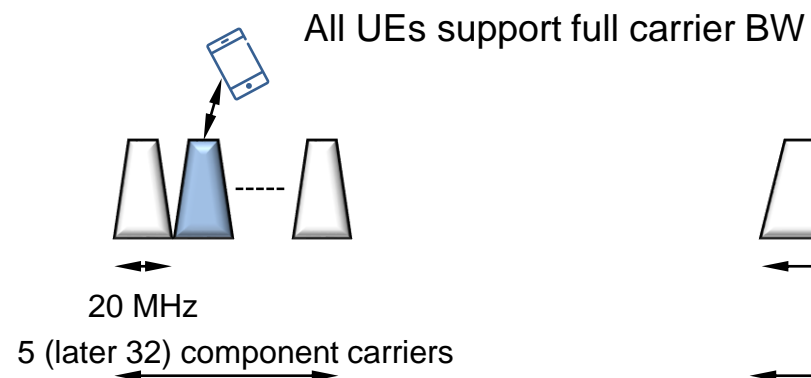
Resource-block grid



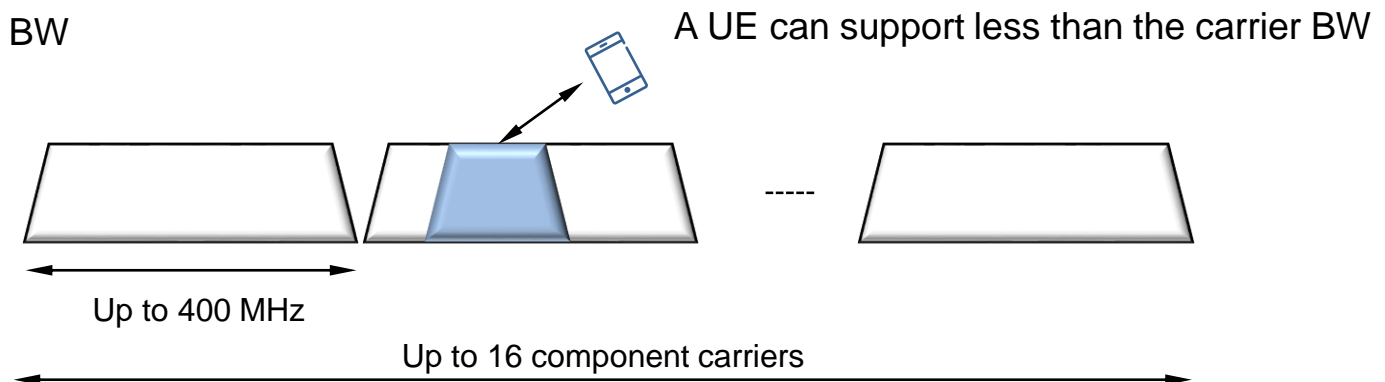
Bandwidths

- Up to 400 MHz component-carrier bandwidth (20 MHz for LTE)
- Up to 16 component carriers
 - Overall bandwidth depends on frequency band
- Not all devices must support the full network carrier bandwidth

LTE

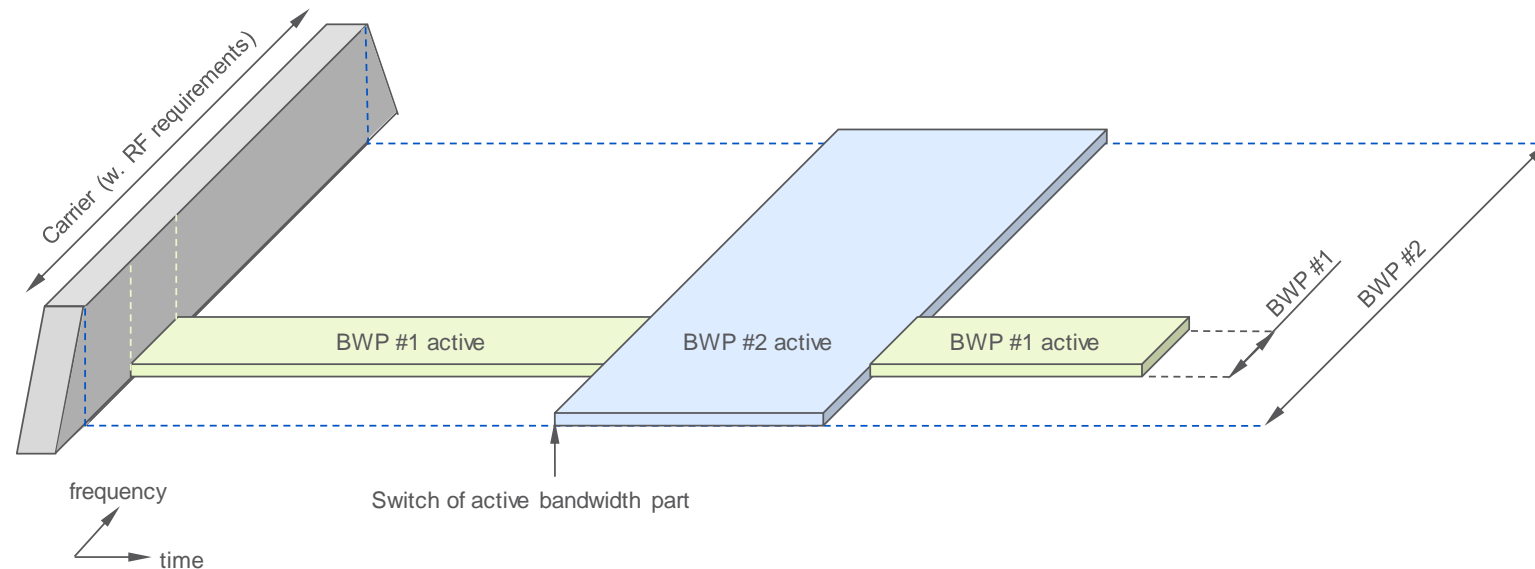


NR



Bandwidth parts

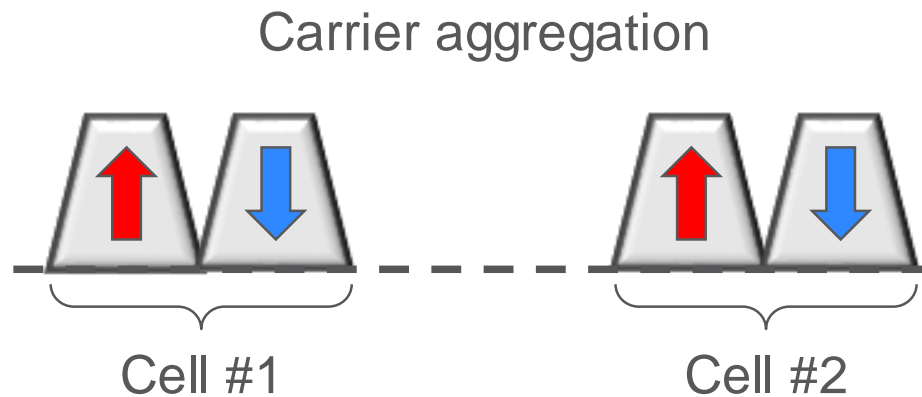
- To support UEs not capable of full carrier bandwidth
- To support bandwidth adaptation (reduced UE power consumption)
- Up to 4 bandwidth parts per carrier, one of which is active
- A UE is not supposed to receive/transmit outside the active bandwidth part
- Many parameters are configured per bandwidth part



Carrier aggregation and supplementary uplink

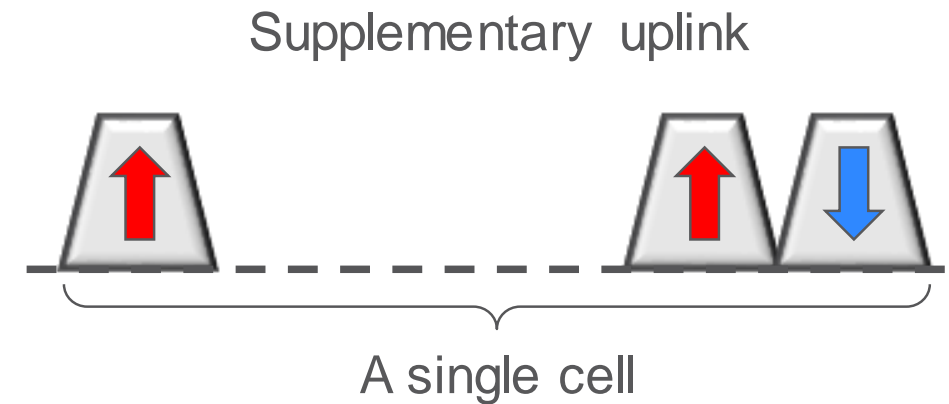
Carrier aggregation (up to 16 carriers)

- Main use case: bandwidth extension



Supplementary uplink

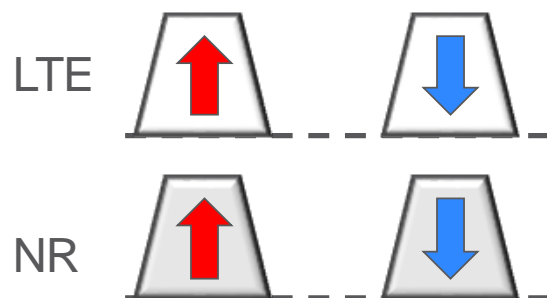
- Main use case: uplink coverage



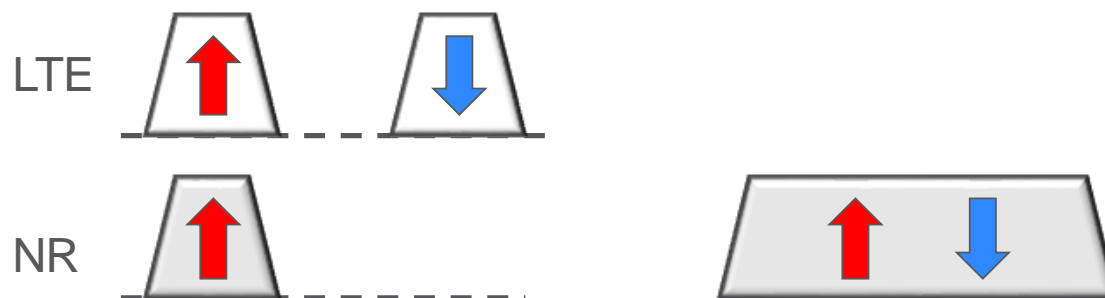
NR-LTE Coexistence

NR can coexist with LTE on the same carrier

Example: NB-IoT or eMTC for MTC on same carrier as NR



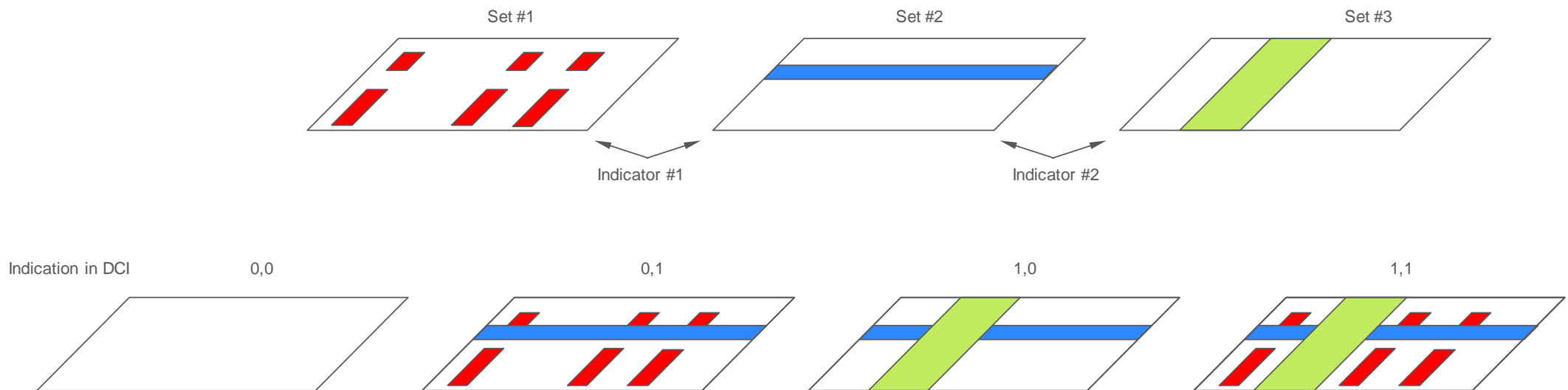
Downlink and uplink co-existence



Uplink-only co-existence

Reserved resources

- To enable coexistence with LTE/NB-IoT on the downlink
 - 📶 Treat LTE CRS as reserved resources
- To facilitate forward compatibility in downlink
 - 📶 Three sets can be configured using a set of bitmaps
 - 📶 Dynamic indication of whether resources are reserved or not



Transport channel processing

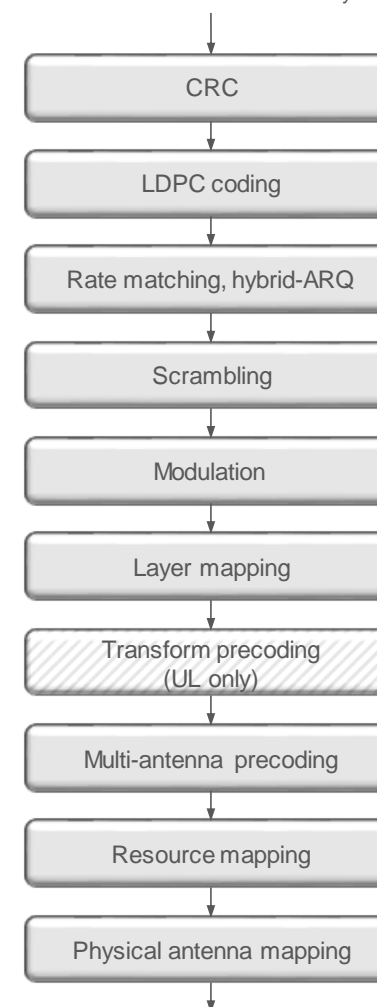
Transport-Channel Processing

Overall transport-channel processing resembles LTE

Main differences:

- LDPC coding
- Multi-antenna handling
- OFDM and DFTS-OFDM in UL

One (or two) transport block(s) of dynamic size delivered from the MAC layer



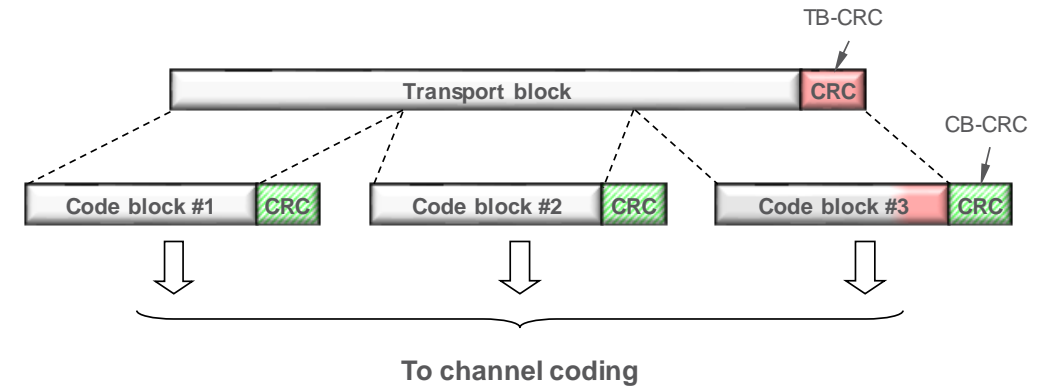
Coding



Code-block segmentation



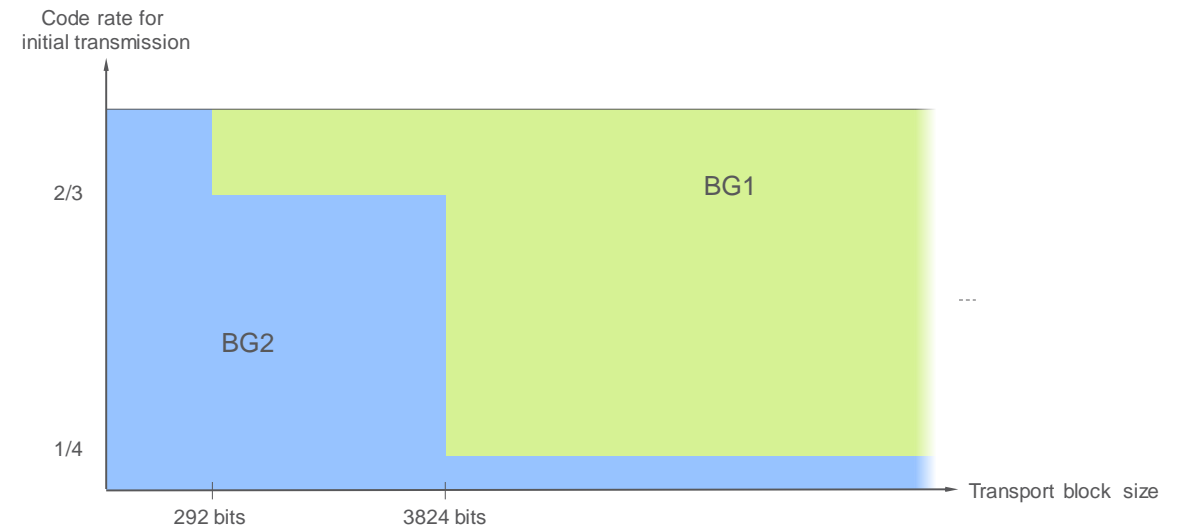
CRC per TB *and* CB (as in LTE)



LDPC coding





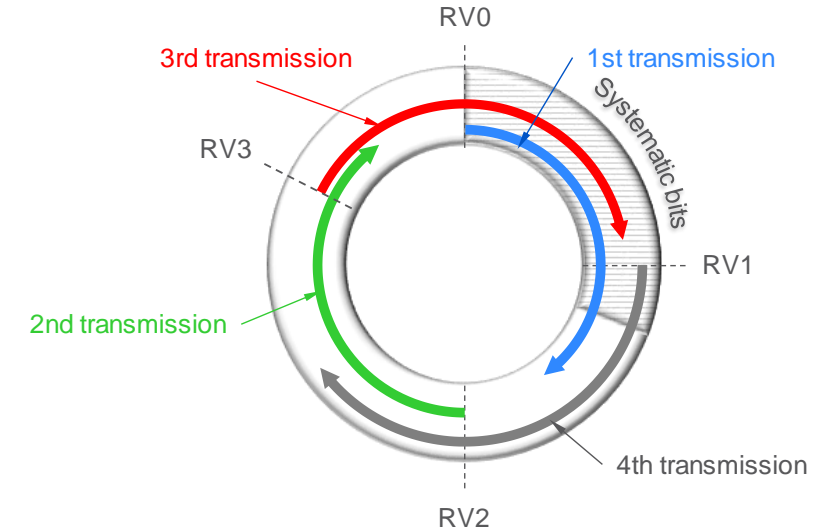
Two base graphs






Rate Matching

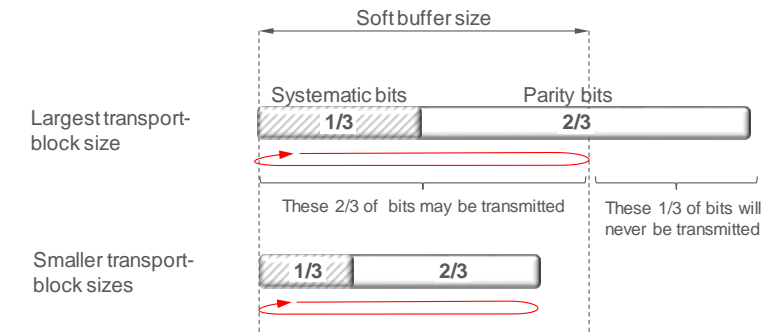
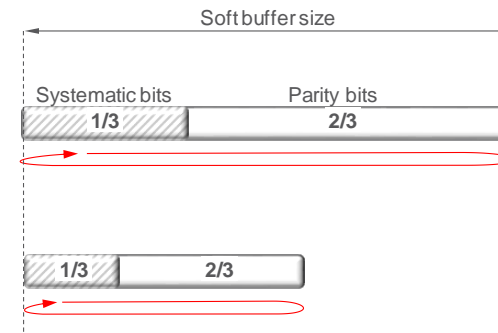
Circular buffer rate matching

-  Some systematic bits removed prior to circular buffer insertion
-  4 different redundancy versions



Limited-buffer rate matching

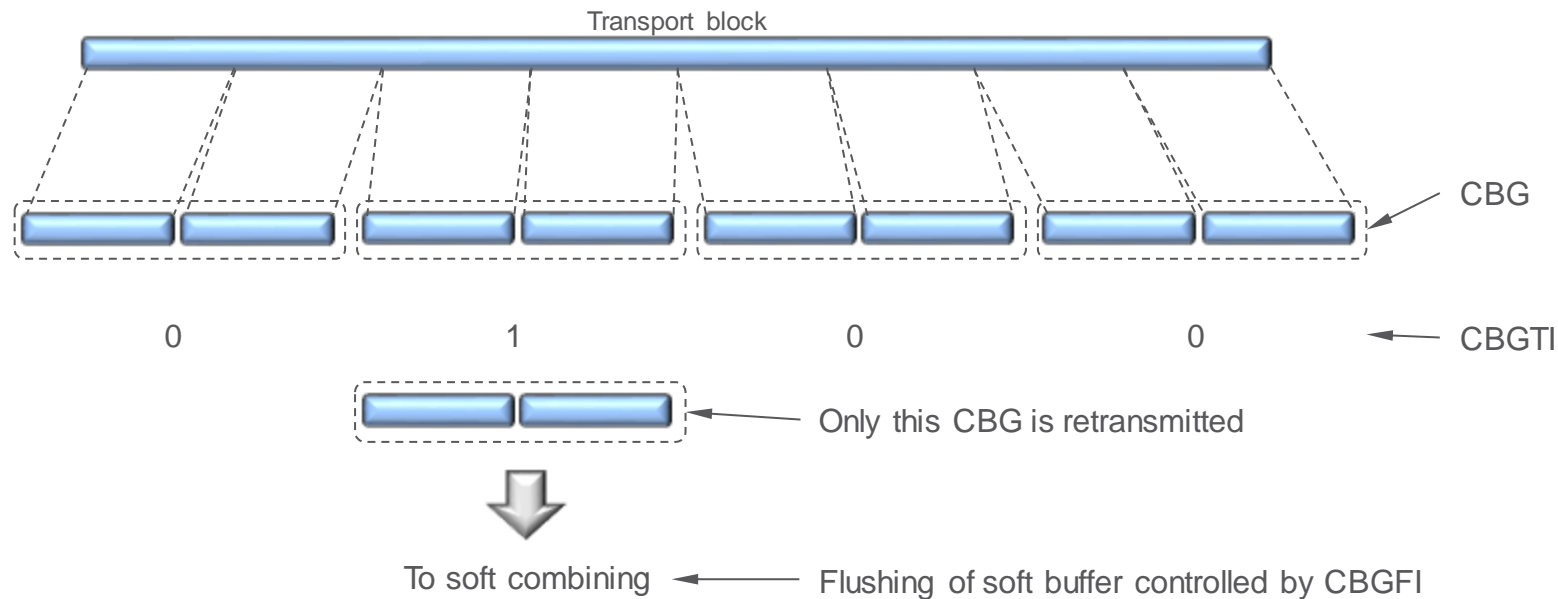
-  To handle limited UE soft-buffer size
-  Determines amount of bits put into the circular buffer
-  Can also be used in UL



Hybrid ARQ

Similar to LTE but with some differences

- Possibility for per-CBG retransmission
- Asynchronous in DL and UL (up to 16 processes)





Control channels

Downlink L1/L2 control signaling



Downlink Control information (DCI), transmitted on PDCCH

-  Similar usage as in LTE (scheduling, ...)

PDCCH

-  The only type of L1/L2 control channel in NR
-  No PCFICH or PHICH (not needed in NR)

Main difference compared to LTE

-  Possibility for beamforming
-  Not necessarily spanning full carrier bandwidth

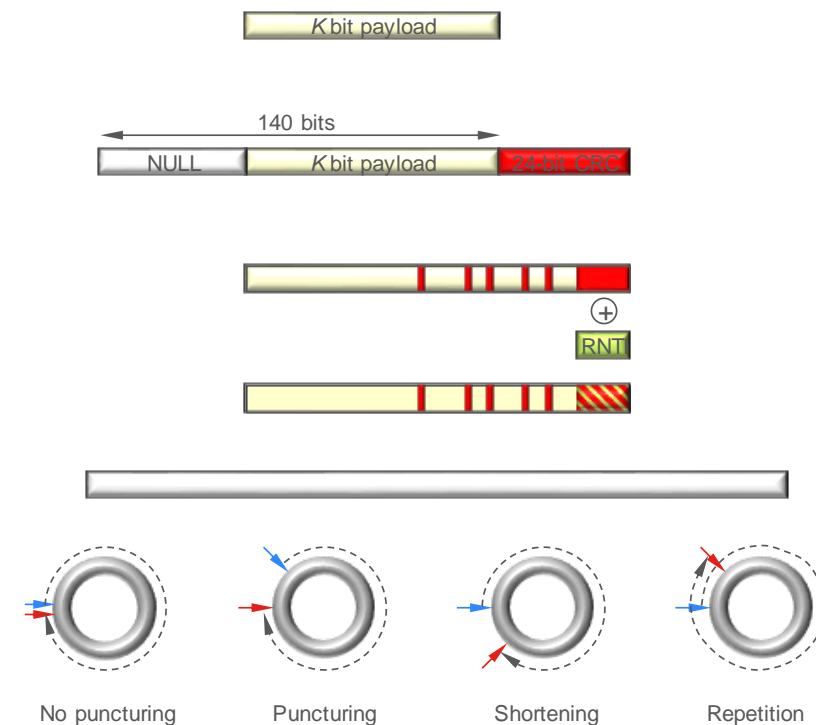
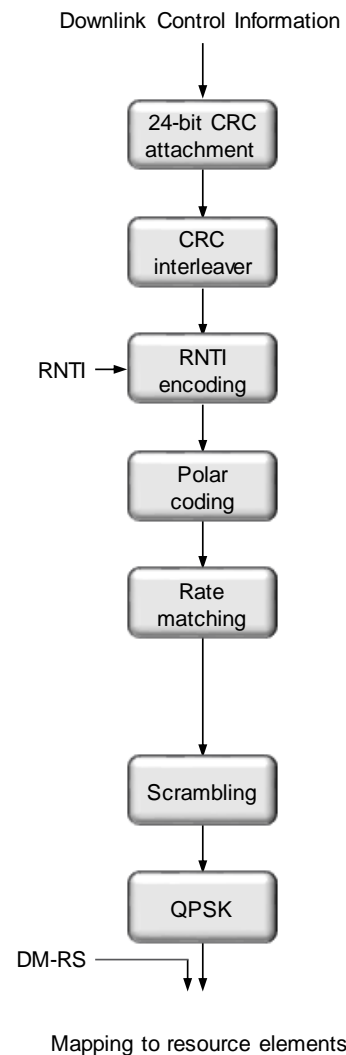
PDCCH Processing

Similar processing chain as for LTE

- Polar coding
- Larger CRC




Each PDCCH

- Independently processed
- Has its own DM-RS





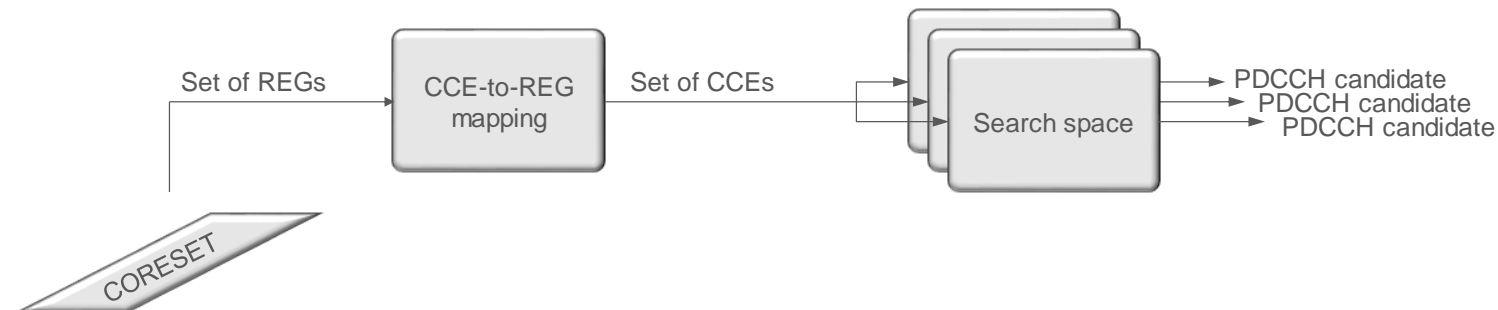
PDCCH Monitoring

CORESET (Control Resource Set)

-  Time-frequency region where the UE monitors for PDCCH transmission
-  Multiple CORESETs can be configured in a UE using RRC signaling
-  CORESET0 obtained from MIB

Search spaces

-  Set of CCEs upon which the UE tries to blindly detect PDCCH transmissions
-  One PDCCH transmitted using aggregation level 1, 2, 4, 8, or 16 CCEs



CORESET



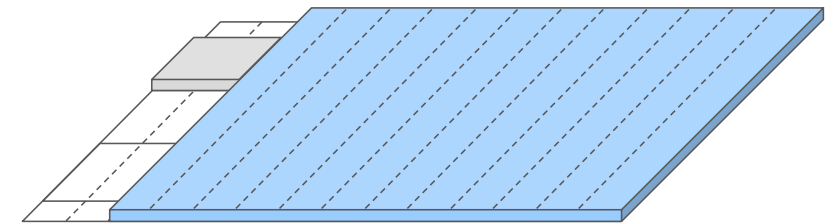
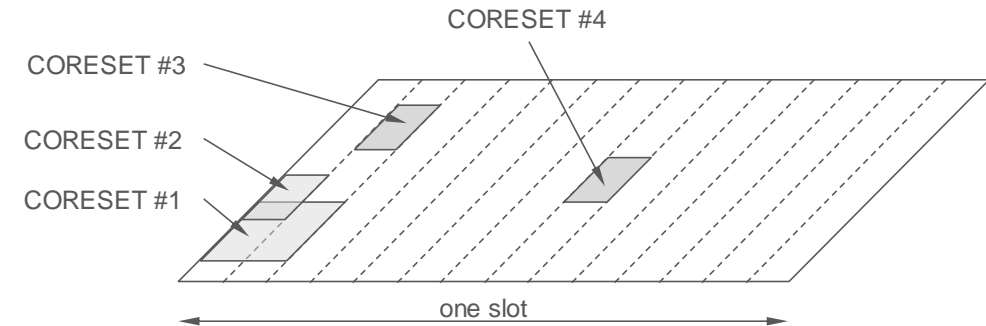
Multiple CORESETs can be configured in one UE

- Not necessarily located at the beginning of the slot
- Frequency span in multiples of 6 RB
- Time span of 1, 2, or 3 OFDM symbols



CORESET resources can be reused for data

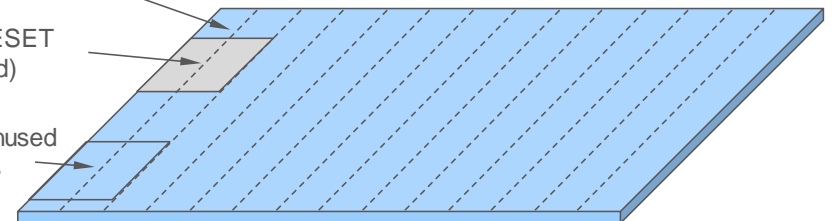
- Use reserved resources mechanism



Data can start before the end of the PDCCH

PDCCH in this CORESET (indicated as reserved)

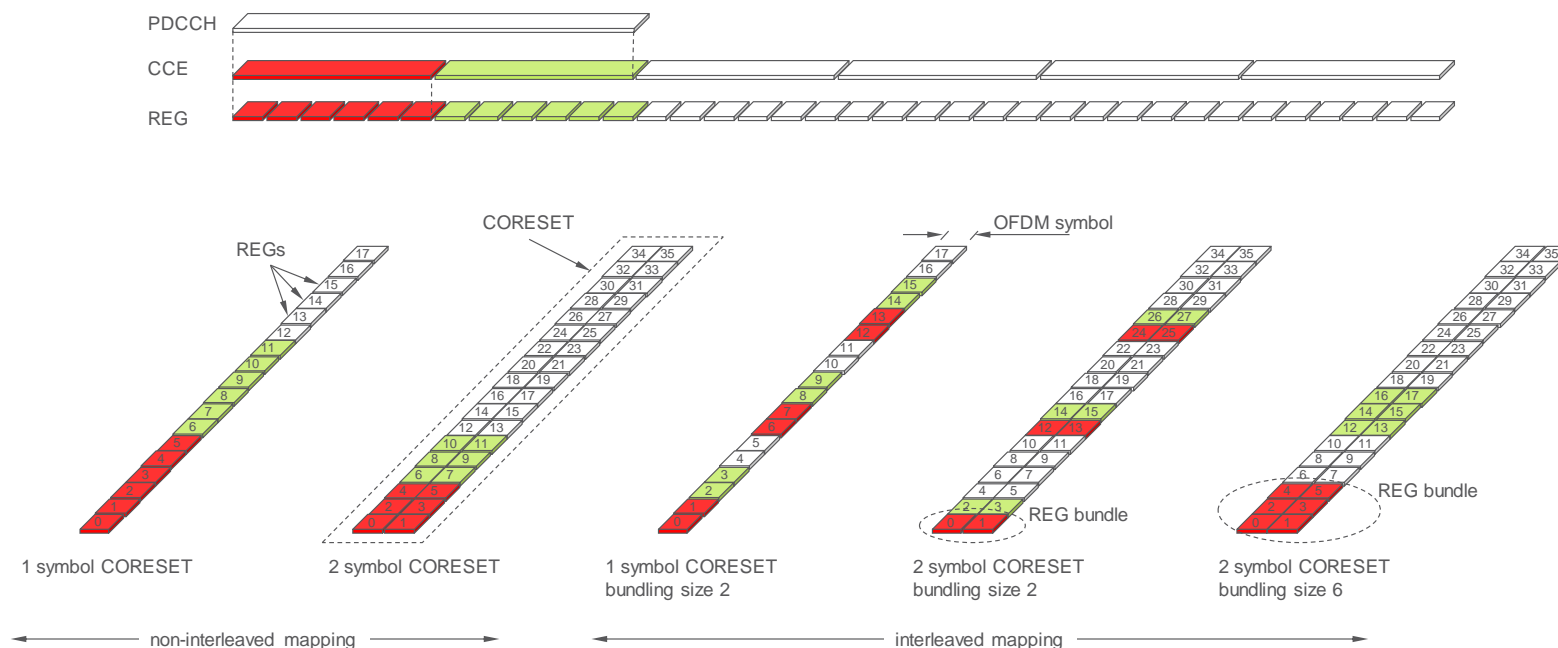
Data scheduled on unused CORESET resources



CCE-to-REG mapping

Each CORESET has an associated CCE-to-REG mapping

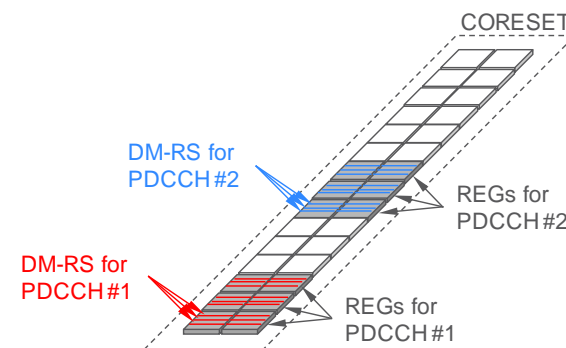
- Interleaved mapping
- Non-interleaved mapping



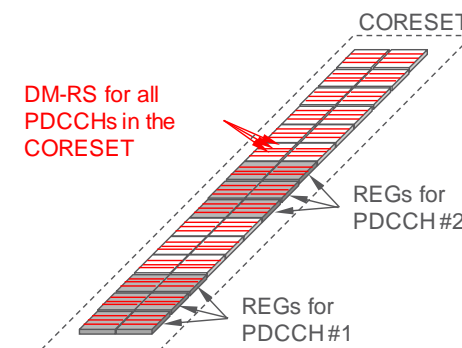
DM-RS and QCL

Each PDCCH has its own DM-RS...
...but possible to configure
'wideband RS'

DM-RS on every 4th subcarrier



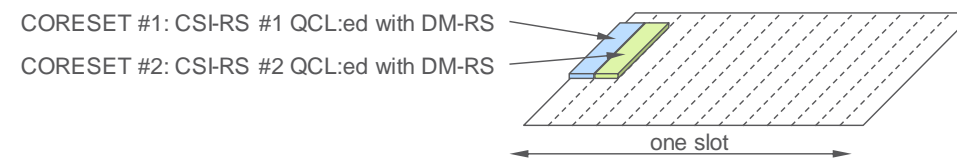
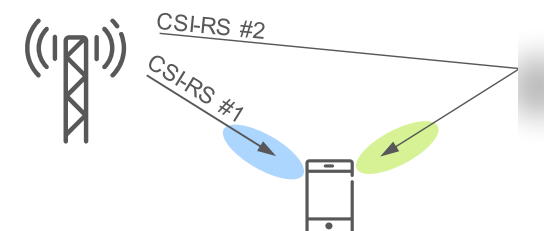
Normal case – DM-RS per PDCCH



Wideband RS

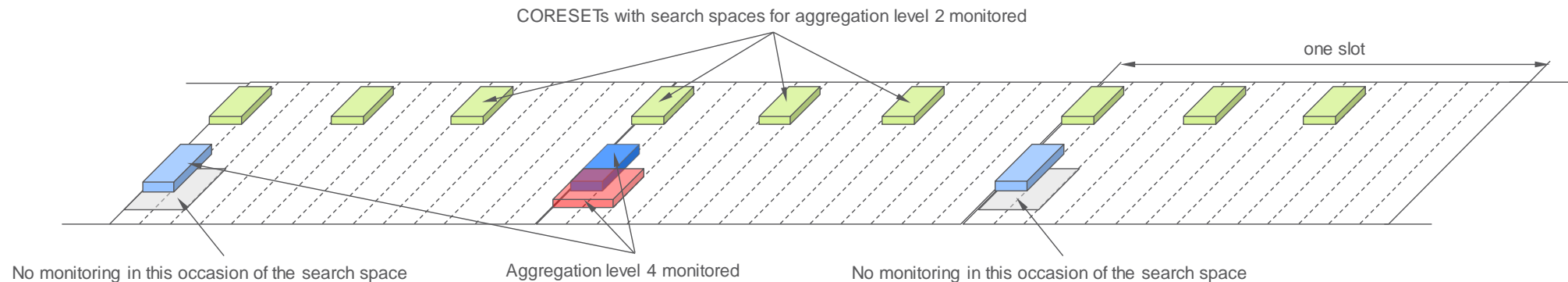
Can configure TCI states (QCL relations) per CORESET

If none configured – assume QCL with SS block



Blind Decoding

- Blind decoding of PDCCH using search spaces and DCI formats
 - Similar concept as in LTE
 - Aggregation level 1, 2, 4, 8, or 16
- Flexible configuration of when, what formats, and what aggregation levels to monitor



DCI formats

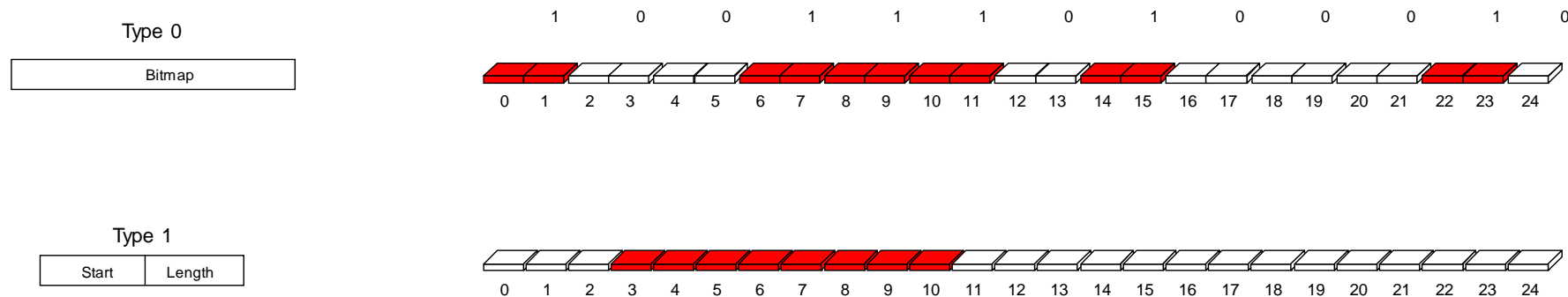
- Format 0-0 – uplink scheduling (fallback format)
- Format 0-1 – uplink scheduling
- Format 1-0 – downlink scheduling (fallback format)
- Format 1-1 – downlink scheduling
- Format 2-0 – slot-format indicator
- Format 2-1 – preemption indicator
- Format 2-2 – PUSCH/PUCCH power control
- Format 2-3 – SRS power control

Field		Format 1-0	Format 1-1
Format identifier		•	•
Resource information	CFI		•
	BWP indicator		•
	Frequency domain allocation	•	•
	Time-domain allocation	•	•
	VRB-to-PRB mapping	•	•
	PRB bundling size indicator		•
	Reserved resources		•
	Zero-power CSI-RS trigger		•
Transport-block related	MCS	•	•
	NDI	•	•
	RV	•	•
	MCS, 2 nd TB		•
	NDI, 2 nd TB		•
	RV, 2 nd TB		•
Hybrid-ARQ related	Process number	•	•
	DAI	•	•
	PDSCH-to-HARQ feedback timing	•	•
	CBGTI		•
	CBGFI		•
Multi-antenna related	Antenna ports		•
	TCI		•
	SRS request		•
	DM-RS sequence initialization		•
PUCCH-related information	PUCCH power control	•	•
	PUCCH resource indicator		•

See 38.212 for an up-to-date detailed list

Frequency-domain resource allocation


- Resource allocation type 0 – bitmap, each bit corresponds to a group of RBs
- Resource allocation type 1 – start and length of RB allocation
- The type to use is RRC configured (always 0, always 1, dynamic selection of 0/1)
 - Uplink transmissions limited to contiguous allocations in Rel-15

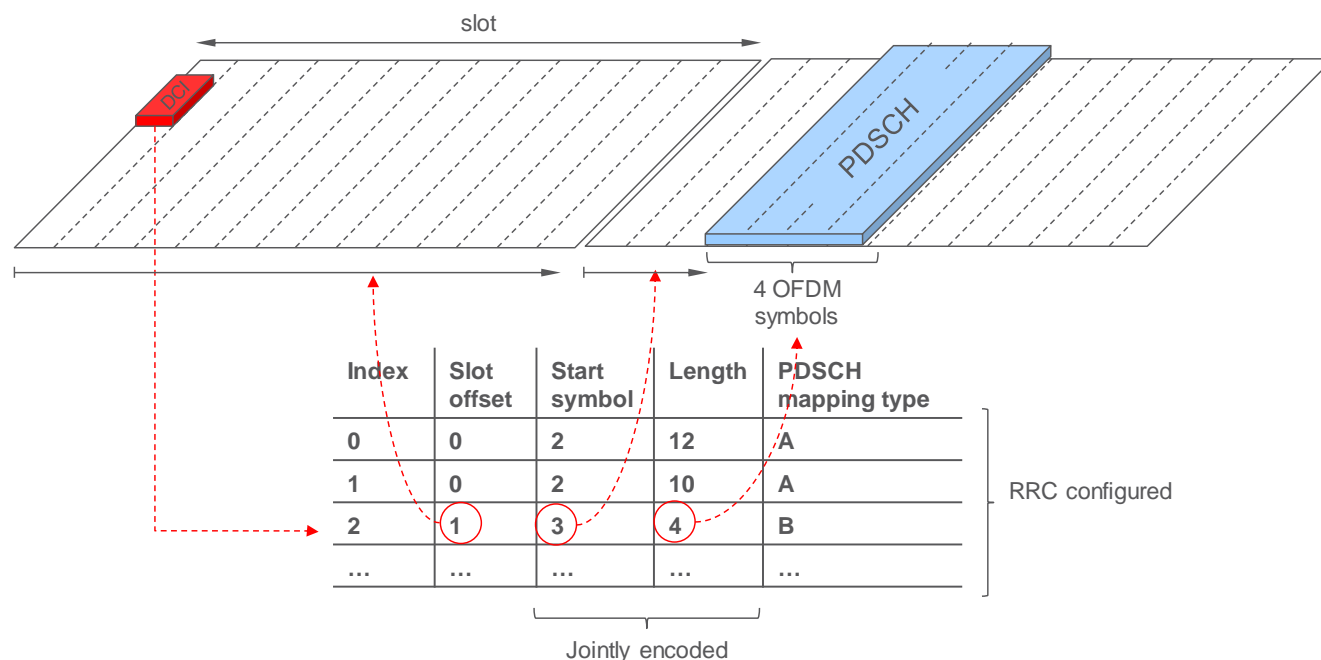


Time-domain resource allocation



Index into RRC-configured table

 Default values specified (needed before configuration)



Time-domain allocation



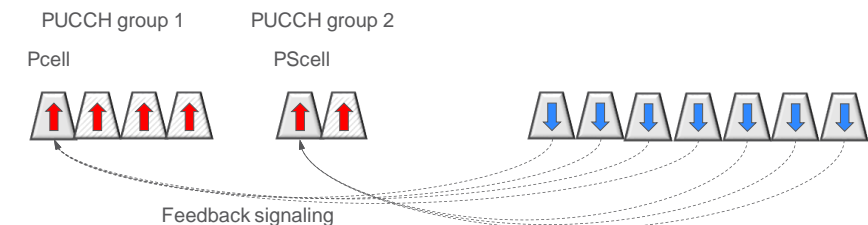
- 🌿 Specification structure supports ‘any’ combination of start, length, and mapping type

- 🌿 Restrictions made on what UEs need to support
 - 📶 Allocations may not span the slot boundary

<ul style="list-style-type: none">— PDSCH mapping type A<ul style="list-style-type: none">— Start symbol: 0, 1, 2, 3 in a slot.— Length: 3 – 14 symbols— PDSCH mapping type B<ul style="list-style-type: none">— Start symbol: any— Length: 2, 4, 7 symbols	<ul style="list-style-type: none">— PUSCH mapping type A<ul style="list-style-type: none">— Start symbol: 0 in a slot— Length: 4 – 14 symbols— PUSCH mapping type B<ul style="list-style-type: none">— Start symbol: any— Length: 2 – 14 symbols
----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------	-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

Uplink L1/L2 control signaling

- ❧ UCI on PUCCH (no simultaneous data) or PUSCH (simultaneous data, 'UCI on PUCCH')
 - 📶 Hybrid-ARQ acknowledgements, channel-state information, scheduling request
- ❧ PUCCH not necessarily at carrier edges (as in LTE)
 - 📶 DCI can indicate the resource to use for UCI
- ❧ Beamforming support: spatial relations between PUCCH and downlink signals can be configured
 - 📶 MAC-CE used to switch between different configurations
- ❧ PUCCH on Pcell (or PScell) in case of CA, similar to LTE



PUCCH formats

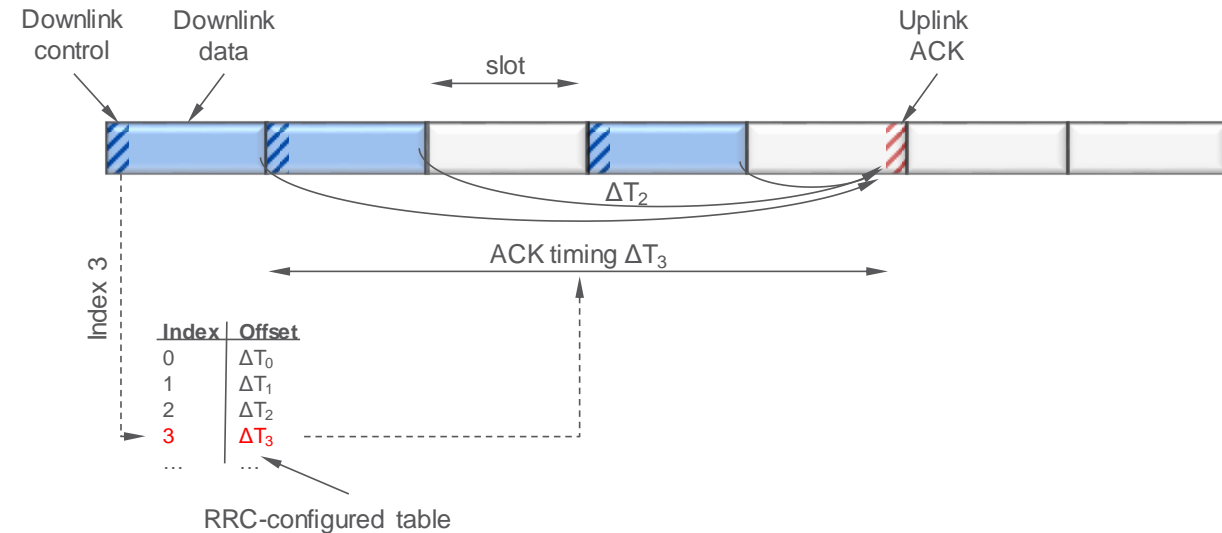
- Five different PUCCH formats
- All designed with low PAPR in mind, can be used irrespective of PUSCH waveform

Payload	Short (1-2 OFDM symbol)	Long (4 – 14 OFDM symbols)
≤2 bits	PUCCH format 0	PUCCH format 1
>2 bits	PUCCH format 2	PUCCH formats 3 and 4

PUCCH Timing

PUCCH timing and resources indicated in the DCI

In essence 'scheduling' of PUCCH



Much faster processing time than in LTE

DM-RS configuration	Device capability	Subcarrier spacing				LT rel
		15 kHz	30 kHz	60 kHz	120 kHz	
Front-loaded	Baseline	0.57 ms	0.36 ms	0.30 ms	0.18 ms	2.3
	Aggressive	0.18 – 0.29 ms	0.08 – 0.17 ms			
Additional	Baseline	0.92 ms	0.46 ms	0.36 ms	0.21 ms	
	Aggressive	0.85 ms	0.4 ms			

Cell search and Random access

Cell Search and System Information Acquisition



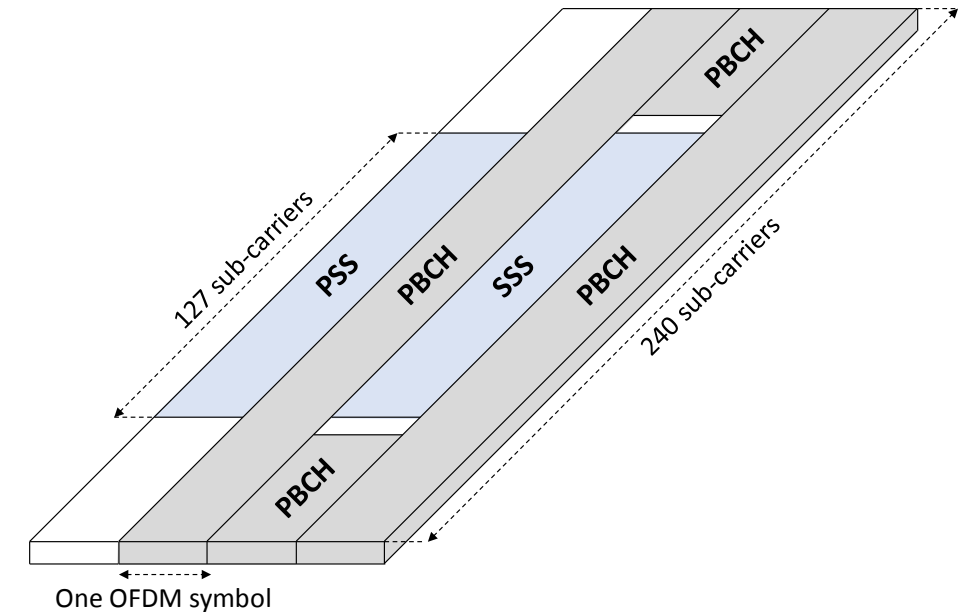
SS Block (SSB)

- 📶 PSS and SSS to obtain synchronization
- 📶 PBCH for (parts of) system information



Main difference compared to LTE

- 📶 Less frequent PSS/SSS/PBCH transmission (20 ms periodicity)
- 📶 Support for beamforming
- 📶 Minimize “always on” broadcasting of system information (possibility for “on demand” delivery)



SS Block

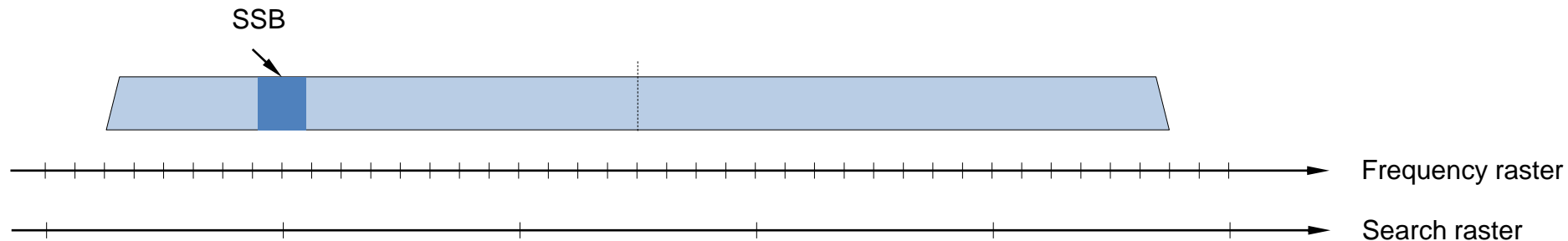
 Subcarrier spacing for SS Block depends on frequency band

Numerology	SSB bandwidth	SSB duration	Frequency range
15 kHz	3.6 MHz	$\approx 285 \mu\text{s}$	FR1 < 3GHz
30 kHz	7.2 MHz	$\approx 143 \mu\text{s}$	FR1
120 kHz	28.8 MHz	$\approx 36 \mu\text{s}$	FR2
240 kHz	57.6 MHz	$\approx 18 \mu\text{s}$	FR2

SS Block

📶 SS Block not necessarily at the center of the carrier (as in LTE)

- 📶 Reason: allow for a search raster sparser than the frequency raster
- 📶 Note: SS block not necessarily aligned with the resource block grid



SS block and Beam Sweeping

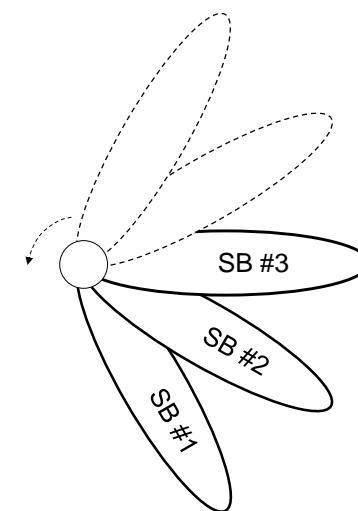
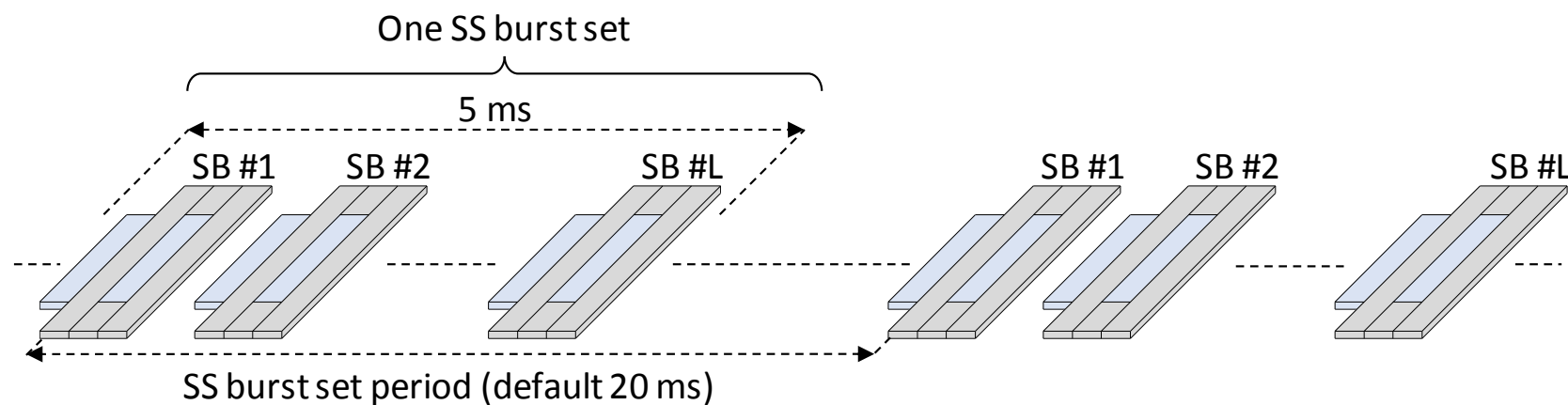


SS burst set



Multiple SS blocks in different beams

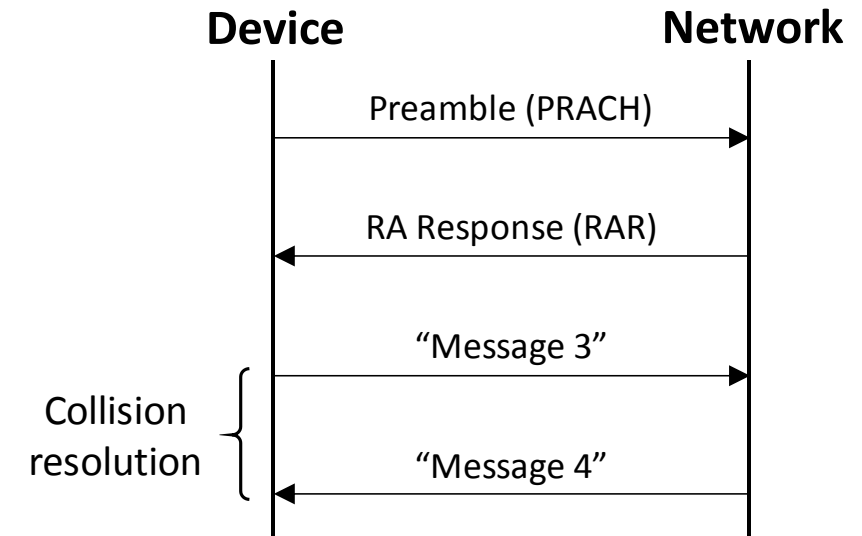
Frequency range	SS blocks per SS burst set
– 3 GHz	4
3 – 6 GHz	8
mm-wave	64



Random Access

Four-step random access procedure

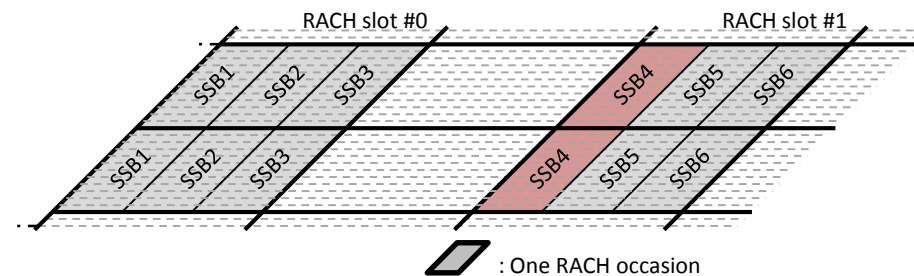
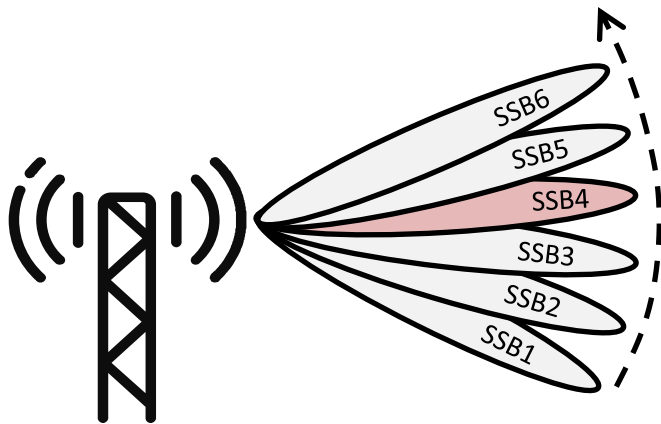
- 1 Preamble transmission
- 2 Random-access response
- 3, 4 Contention resolution



Beam Establishment

🌿 Different SS block time indices are associated with different RACH time/frequency occasions


- 📶 SIB1 provides “number of SS-block time indices per RACH time/frequency occasion”
- 📶 SSB time indices associated with RACH occasions, first in frequency, then in time within a slot, and last in time between slots



Supplementary Uplink





System information provides

-  separate RACH configurations for 'normal' and 'supplementary' uplinks
-  threshold for carrier selection



Measure downlink RSRP and select uplink carrier for random access

-  RSRP **above** threshold ➡ random-access on non-SUL carrier
-  RSRP **below** threshold ➡ random-access on SUL carrier

Conclusions

- NR addresses a broad range of use cases with a flexible physical layer structure
- Key enablers include
 - Ultra-lean design
 - Operability in a wide spectrum range
 - Low latency
 - Forward compatible design
 - Advanced multi-antenna techniques

For more Information:



info@3gpp.org



www.3gpp.org

Search for WIDs at <http://www.3gpp.org/specifications/work-plan> and http://www.3gpp.org/ftp/Information/WORK_PLAN/ (See excel sheet)



NR Physical Layer Design: NR MIMO

Younsun Kim
3GPP TSG RAN WG1 Vice-Chairman (Samsung)

Considerations for NR-MIMO Specification Design

NR-MIMO Specification Features

Key Features of NR-MIMO

- Make cellular communications over millimeter wave (mmWave) spectrum a reality
 - 📶 ITU's 5G requirement to support a peak rate of 20Gbps would not be possible without mmWave
- Improve system performance well beyond LTE
 - 📶 ITU's 5G requirement is to achieve spectral efficiency of 3 times that of LTE
- Provide sufficient flexibility for wide range of 5G realizations
 - 📶 Considering deployment scenarios, network implementations, supportable spectrum bands, etc

Higher Frequency Bands

(Coverage for mmWave)

Multi-beam operation

Performance

(Enhanced spectral efficiency)

**Enhanced channel status
information (CSI)**

Flexibility

(Deployment, implementation, spectrum, ...)

**Enhanced reference signals,
transmission schemes, etc**

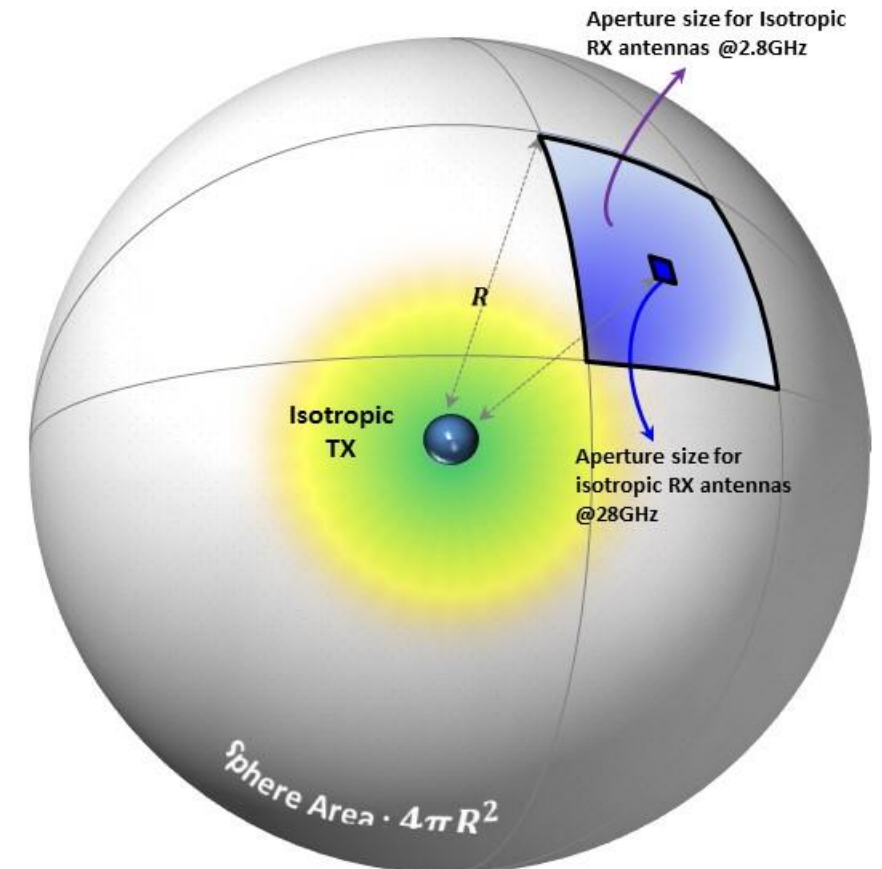
Higher Frequency Band

Pathloss is proportional to the square of frequency

$$\begin{aligned}
 P_{RX} &= P_{TX} \underbrace{G_{TX} G_{RX}}_{= 1 \text{ for Isotropic}} \underbrace{\left(\frac{\lambda}{4\pi R} \right)^2}_{\text{Path-loss}} \\
 &= P_{TX} \cdot 1 \cdot 1 \cdot \underbrace{\left(\frac{\lambda^2}{4\pi} \right)}_{\text{Aperture size}} \underbrace{\left(\frac{1}{4\pi R^2} \right)}_{\text{Spherical area}} \\
 &= P_{TX} \cdot 1 \cdot 1 \cdot \left(\frac{c^2}{4\pi \cdot \underbrace{f^2}_{\text{Carrier frequency}}} \right) \left(\frac{1}{4\pi R^2} \right) \quad (c: \text{speed of light})
 \end{aligned}$$

2.8GHz vs 28GHz

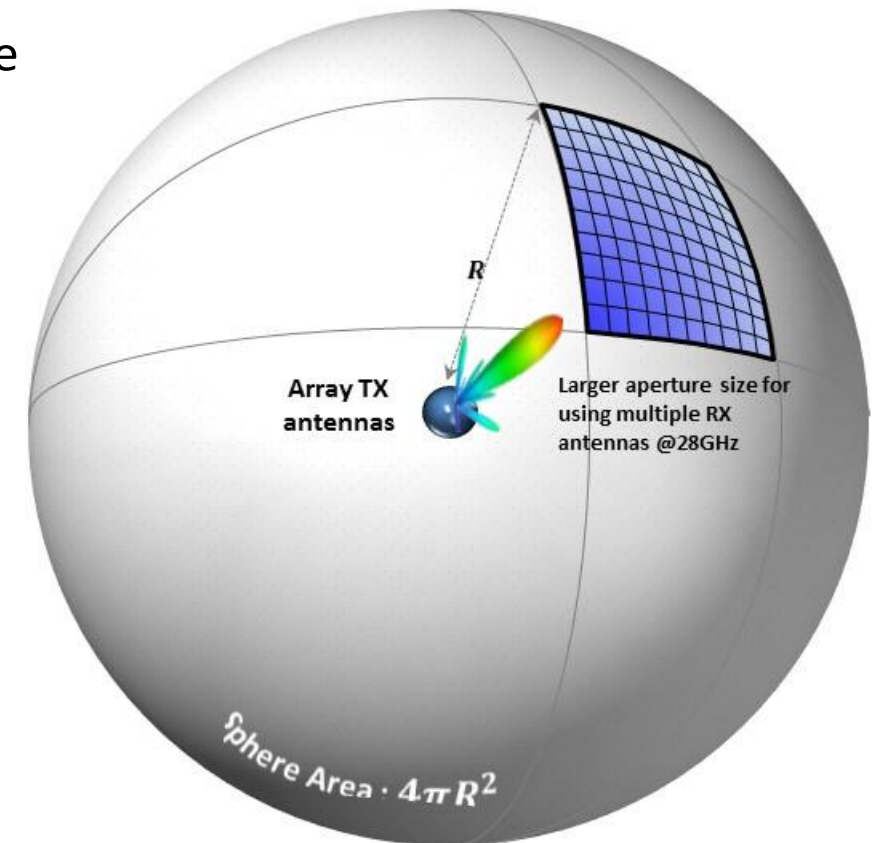
	2.8 GHz	28 GHz
RX Aperture Size	9.135 cm ²	0.091 cm ²
Path-loss (R=1m)	-41.4 dB	-61.4 dB



Higher Frequency Band

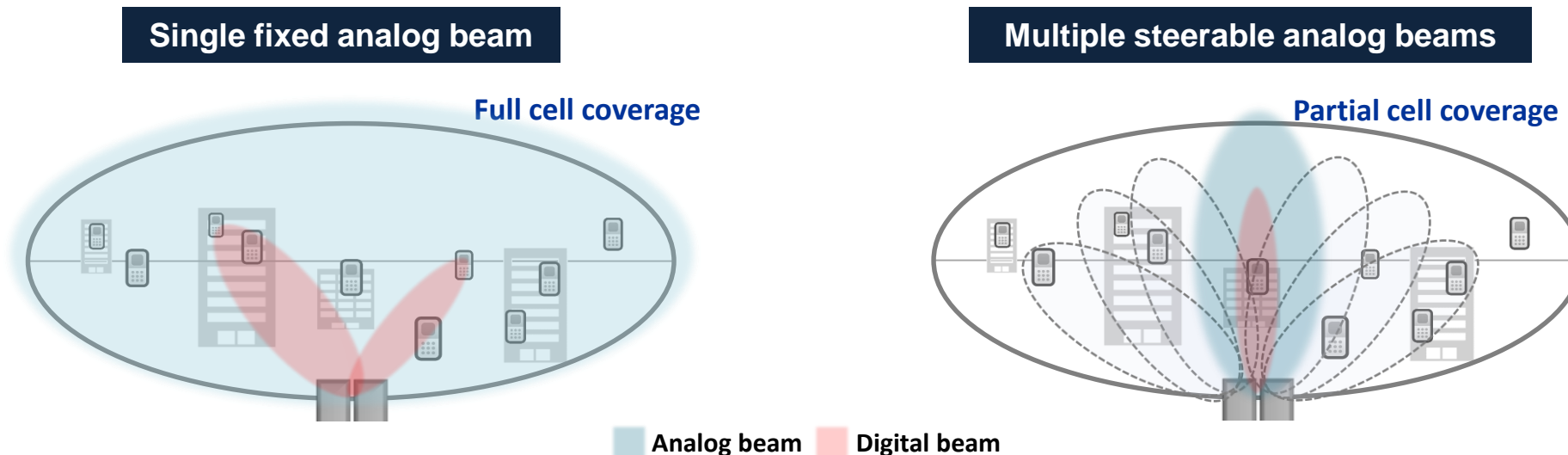
- Pathloss of higher frequencies can be overcome by utilizing multi-antennas
 - 📶 Multiple Rx antennas to effectively increase aperture size
 - 📶 Multiple Tx antennas to direct energy

- NR facilitates the use of multi-antennas in at every stage of the radio operation:
 - 📶 Initial/random access
 - 📶 Paging
 - 📶 Data/control information
 - 📶 Mobility handling



Analog and Digital Beamforming

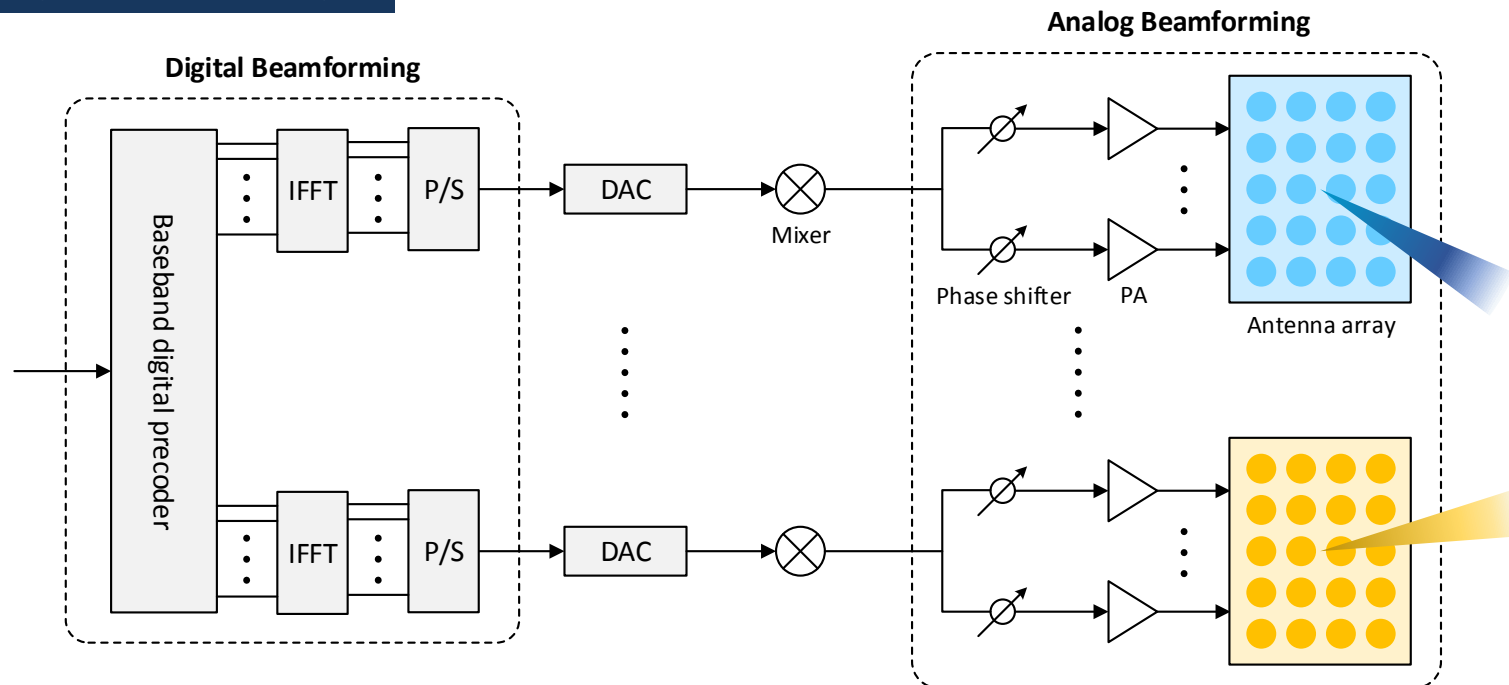
- 🟢 LTE was designed on the assumption of a fixed analog beam per cell
 - 📶 The analog beam provides full coverage throughout the cell at any given time instance
- 🟢 NR was designed on the concept of multiple steerable analog beams per cell
 - 📶 Each analog beam concentrates on a part of a cell at a given time so as to overcome large pathloss
- 🟢 Digital beamforming is applied on top of analog beamforming in both LTE and NR



Hybrid Beamforming

- 🌿 A combination of digital and analog beamforming, or 'hybrid beamforming' can be used to realize large BF gains without excessively increasing implementation complexity

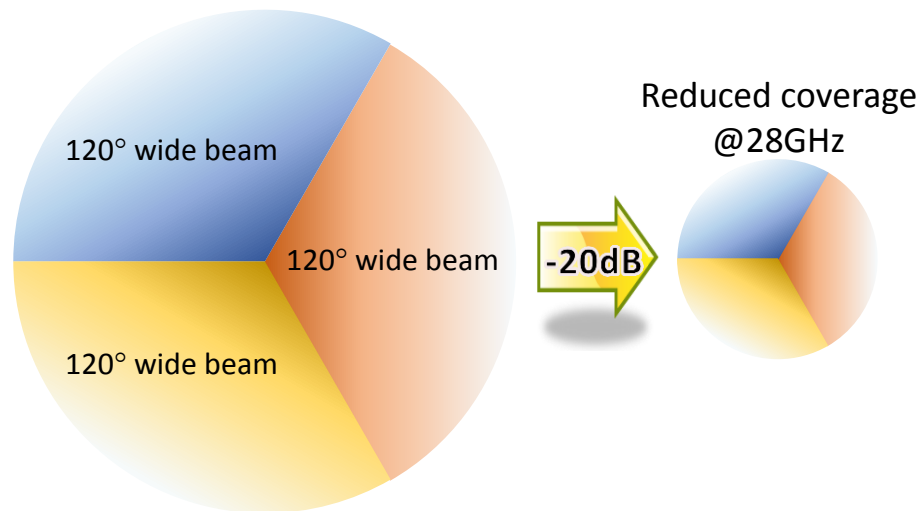
Example of hybrid beamforming



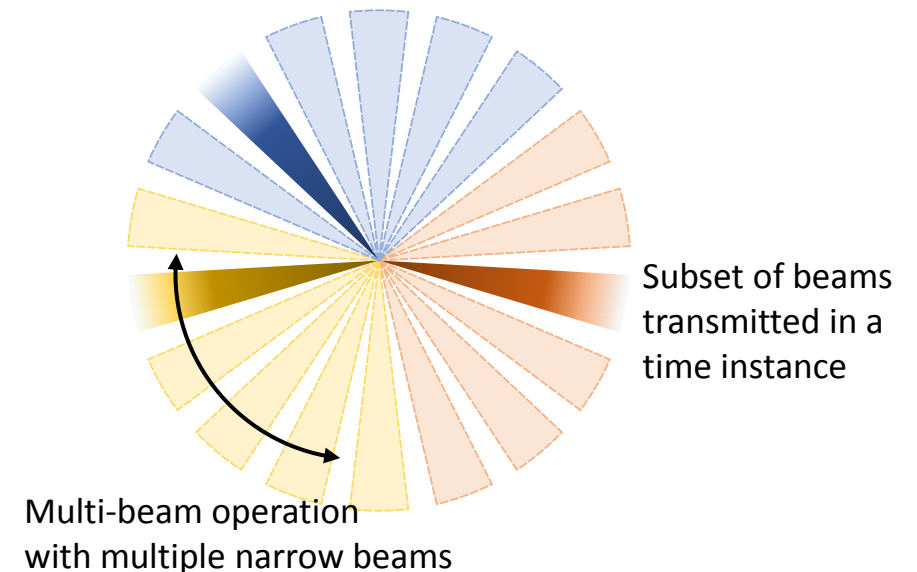
Single vs Multi-Beams

- 🌿 In lower frequencies, a single beam can be used to provide wide coverage
- 🌿 In higher frequencies, multiple beams can be used to extend coverage

Single beam per sector @2.8GHz



Multi-beam per sector @28GHz



Considerations for NR-MIMO Specification Design

NR-MIMO Specification Features

Comparison of NR-MIMO vs LTE MIMO

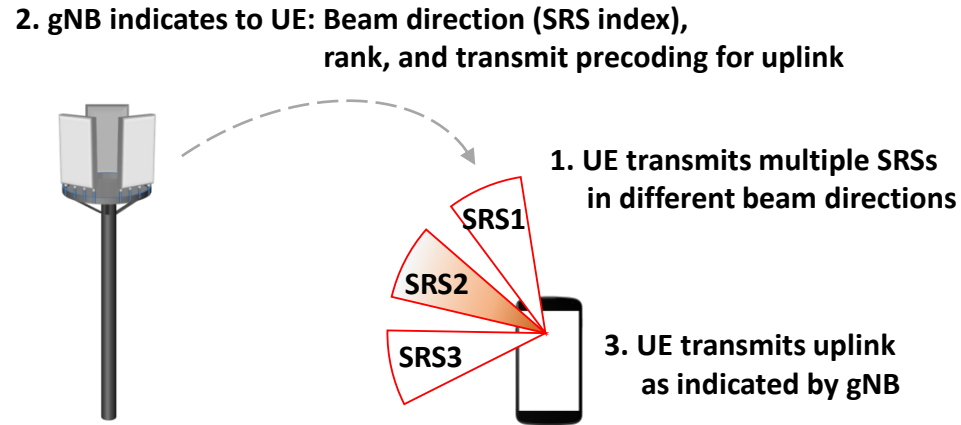
	LTE Rel-8	LTE-A Pro Rel-15	NR Rel-15
Purpose	<ul style="list-style-type: none"> Spectral efficiency enhancement 	<ul style="list-style-type: none"> Spectral efficiency enhancement 	<ul style="list-style-type: none"> Coverage enhancement (especially for above 6GHz) Spectral efficiency enhancement
Multi-beam operation	<ul style="list-style-type: none"> No specification support 	<ul style="list-style-type: none"> No specification support 	<ul style="list-style-type: none"> Beam measurement, reporting Beam indication Beam failure recovery
Uplink transmission	<ul style="list-style-type: none"> Up to 4 layers per UE Up to 8 layers for MU-MIMO (cyclic shifts for ZC-sequence) 	<ul style="list-style-type: none"> Up to 4 layers per UE Up to 8 layers for MU-MIMO (cyclic shifts for ZC-sequence) 	<ul style="list-style-type: none"> Up to 4 layers per UE Up to 12 layers for MU-MIMO (orthogonal ports)
Downlink transmission	<ul style="list-style-type: none"> Up to 4 layers per UE 	<ul style="list-style-type: none"> Up to 8 layers per UE Up to 4 layers for MU-MIMO (orthogonal ports) 	<ul style="list-style-type: none"> Up to 8 layers per UE Up to 12 layers for MU-MIMO (orthogonal ports)
Reference signal	<ul style="list-style-type: none"> Fixed pattern, overhead Up to 4 TX antenna ports (CRS) 	<ul style="list-style-type: none"> Fixed pattern, overhead Up to 32 TX antenna ports (CSI-RS) 	<ul style="list-style-type: none"> Configurable pattern, overhead Up to 32 TX antenna ports (CSI-RS) Support for above 6GHz

Uplink Transmission

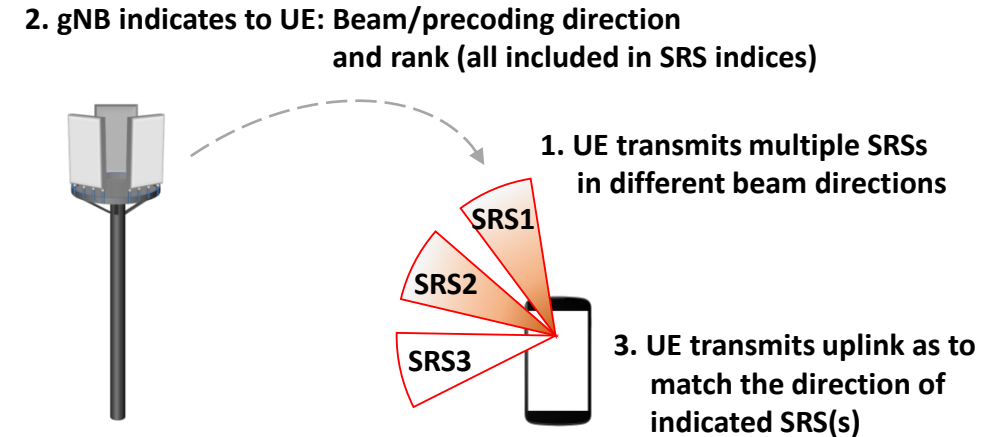
Codebook based and non-codebook based uplink transmissions are supported

- Codebook based: gNB indicates the uplink beam direction and precoding to the UE
- Non-codebook based: gNB only indicates the beam direction only

Codebook based Uplink Transmission



Non-Codebook based Uplink Transmission



Uplink MIMO capability

- Up to rank 4 per UE, up to 12 co-scheduled UEs with orthogonal DM-RS ports

Downlink Transmission

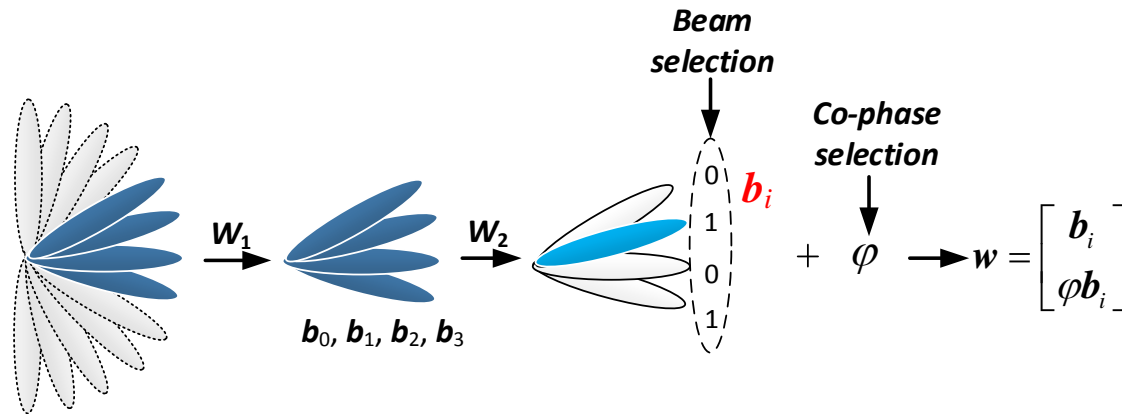
- gNB has full control of downlink precoding which can be determined either from channel status report or SRS transmission from UE
 - 📶 UE has no knowledge of actual precoding applied at the gNB (UE transparent)
 - 📶 UE only requires the combined effect of precoding and channel for demodulation purpose

- Downlink MIMO capability
 - 📶 Up to rank 8 per UE
 - 📶 Up to 12 co-scheduled UEs with orthogonal DM-RS ports

Channel Status Info: Type-I & Type-II

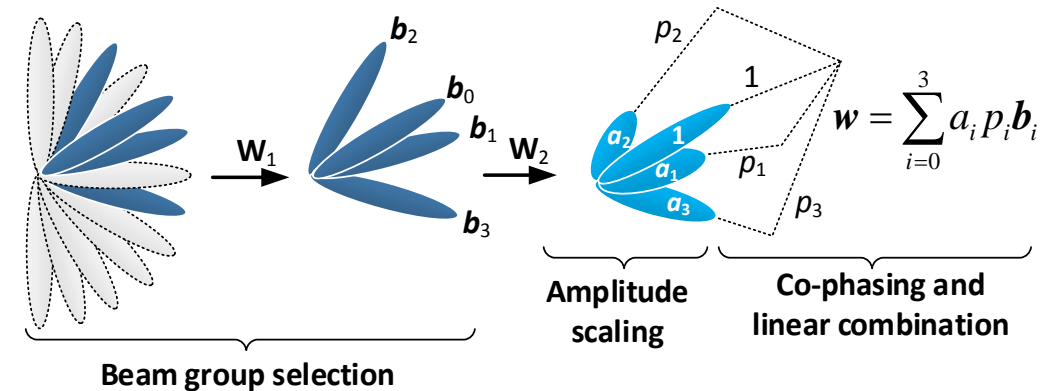
- Two different Channel Status Information (CSI) types are supported in NR
 - Type-I which is optimized for Single User MIMO transmission with smaller uplink overhead
 - Type-II which is optimized for Multi-User MIMO transmission with finer channel information and as a consequence, larger uplink overhead

Type-I Channel Status Information



Terminal selects beam and co-phase (relative phase difference between X-pol antennas) coefficient

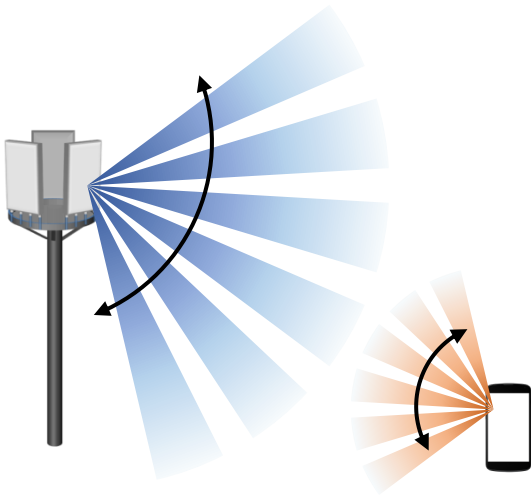
Type-II Channel Status Information



Terminal selects multiple beams, amplitude scaling, and phase coefficients for linear combination between the beams

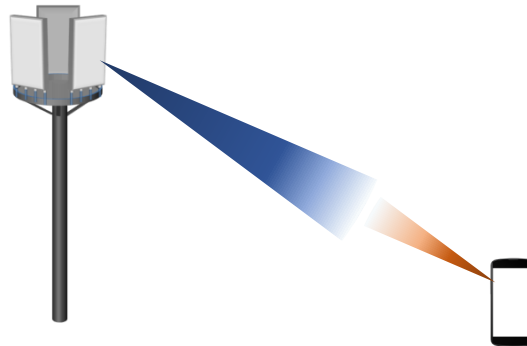
Multi-Beam Operation in NR

Beam Measurement/Reporting



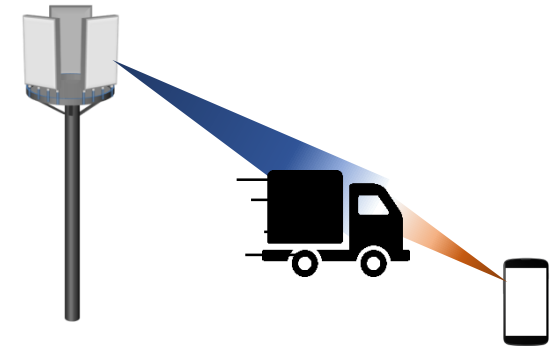
Terminal measures different combinations of TX-RX beams for initial selection and further refinement

Beam Indication



NW indicates beam direction for reference signals, and control/data transmission on downlink/uplink

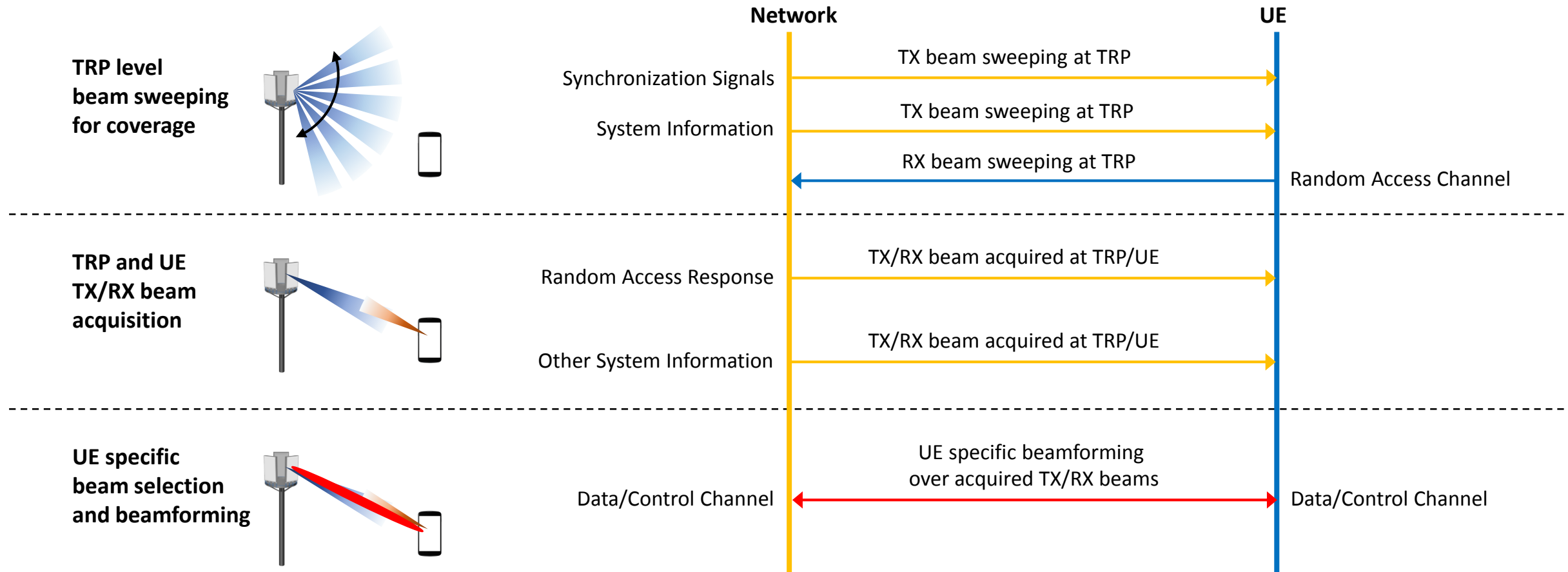
Beam Failure Report



A low latency procedure for recovering from beam failure

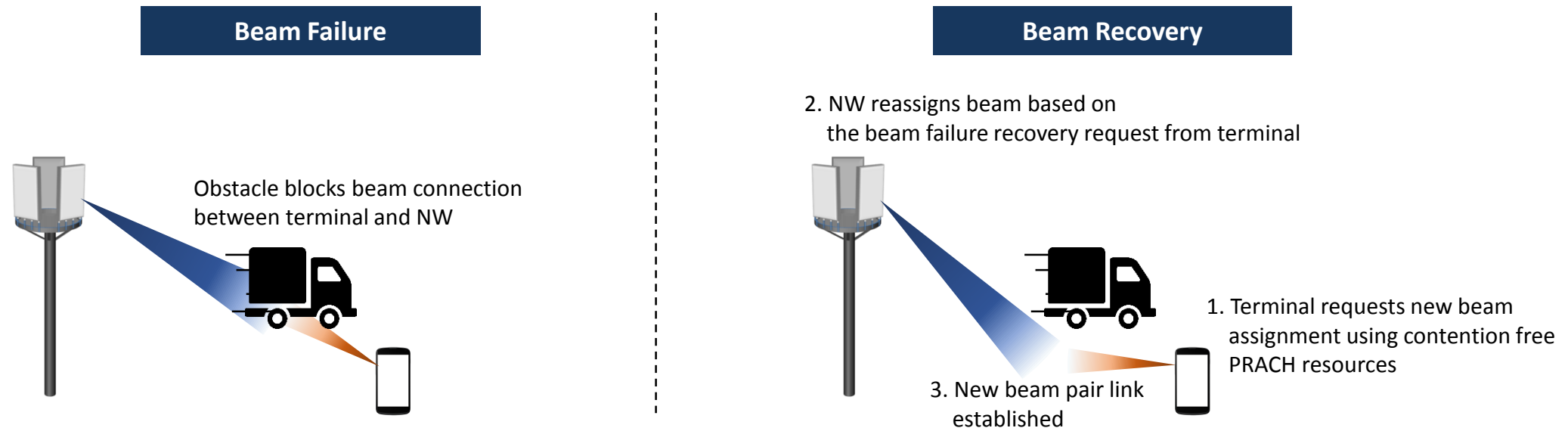
Multi-Beam Operation in NR

Multi-Beam Operation for Initial Access and Data/Control Channel



Beam Failure Recovery

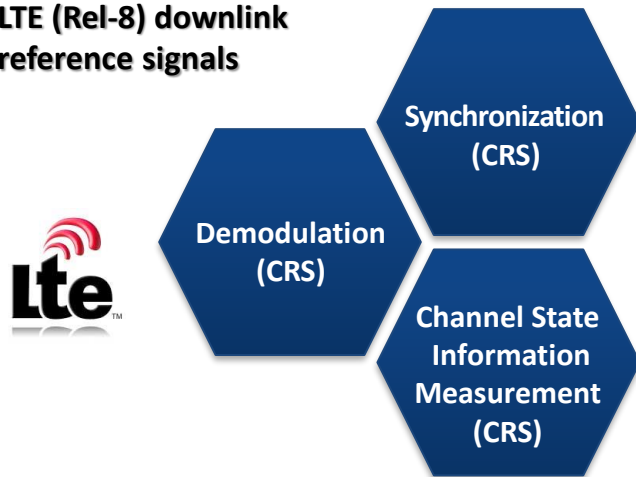
- Due to the narrow beam width when multi-beam operation is in place, the link between the network and terminal is prone to beam failures
- Unlike out-of-coverage situations, beam failure tends to have dynamic time profile
- Beam failure recovery allows for prompt beam recovery using L1 procedures



NR Reference Signals

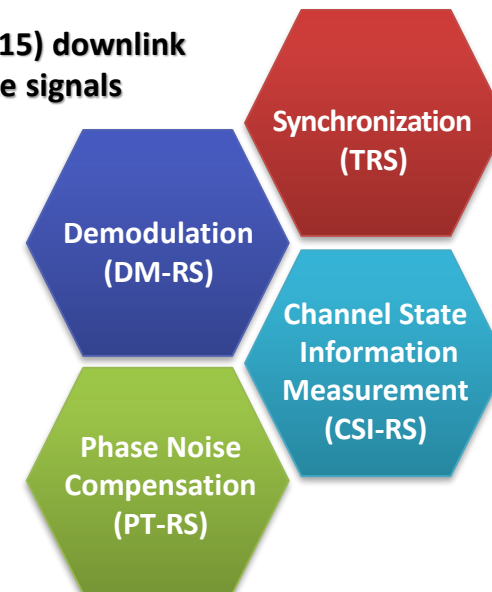
- 🌿 LTE has a 'one size fits all' downlink reference signal design: CRS
 - 📶 Limits flexible network deployments, not network energy efficient, not applicable for higher spectrum (>6GHz), not MIMO friendly for large number of antennas
- 🌿 NR downlink reference signals are tailored for specific roles and can be flexibly adapted for different deployment scenarios and spectrum

LTE (Rel-8) downlink
reference signals



CRS: Cell-Specific RS

NR (Rel-15) downlink
reference signals



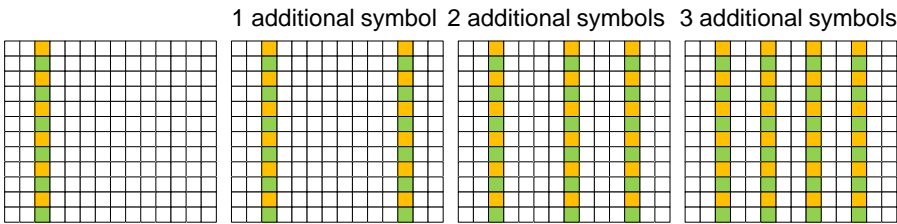
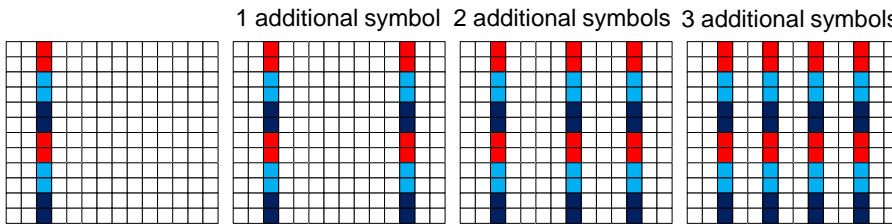
TRS: Tracking RS
DMRS: DeModulation RS
CSI-RS: Channel Status Info RS
PT-RS: Phase Tracking RS



NR Reference Signals: DM-RS

Designed for downlink/uplink channel estimation → coherent demodulation

NR supports two different types of DMRS

	NR Type 1 DM-RS	NR Type 2 DM-RS
Orthogonal Ports	Up to 8	Up to 12
Flexibility	Can be adapted for frequency/time selectivity, robustness, number of co-scheduled UEs for MU-MIMO, etc	
Waveform	CP-OFDM (UL/DL) or DFT-S-OFDM (UL)	CP-OFDM only (UL/DL)
Design (figure for single symbol DM-RS)	IFDMA based 	Frequency domain orthogonal cover code based 
Overhead/Port	Higher	Lower

NR Reference Signals: CSI-RS / TRS

 CSI-RS is designed for downlink measurement → reporting channel status info




 Three different types of CSI-RS is supported: Periodic, aperiodic, and semi-persistent CSI-RS

	Periodic CSI-RS	Aperiodic CSI-RS	Semi-Persistent CSI-RS
Orthogonal Ports	Up to 32	Up to 32	Up to 32
Time domain behavior	Periodic transmission once configured	Single transmission when triggered	Periodic transmission once activated until deactivated
Activation /Deactivation	RRC signaling	L1 signaling	MAC CE
Characteristics	No L1 overhead	Low latency	Hybrid of periodic and aperiodic CSI-RS

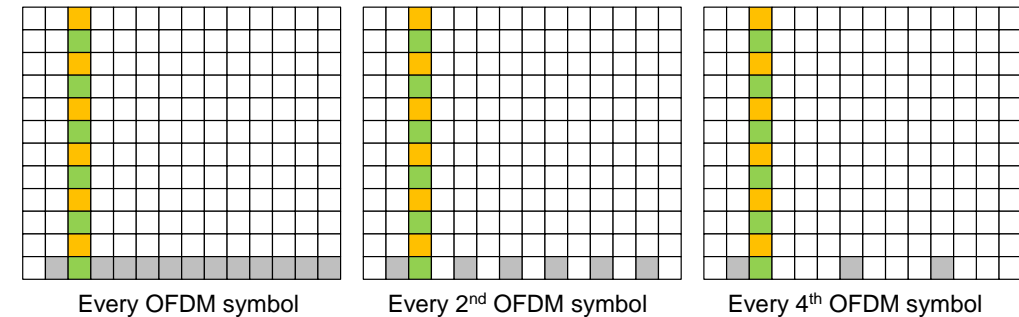
 TRS is designed for time/frequency tracking and estimation of delay/Doppler spread

 Configured as a CSI-RS with specific parameter restriction (time/freq location, RE pattern, etc)

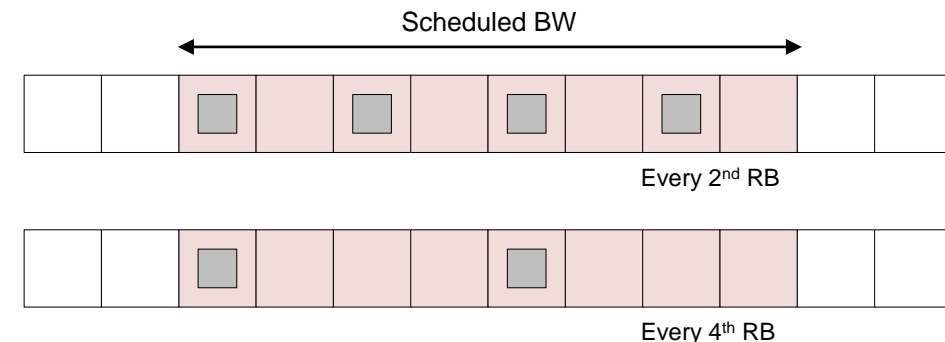
NR Reference Signals: PTRS

-  PTRS is designed for compensation of downlink/uplink phase noise compensation
-  'Associated' with DM-RS so that receiver can compensate for phase noise during demodulation
-  PTRS density in time, frequency is associated with scheduled MCS, bandwidth, respectively

Scheduled MCS	Time domain density
$0 \leq \text{MCS} < \text{MCS}_1$	No PTRS
$\text{MCS}_1 \leq \text{MCS} < \text{MCS}_2$	Every OFDM symbol
$\text{MCS}_2 \leq \text{MCS} < \text{MCS}_3$	Every 2 nd OFDM symbol
$\text{MCS}_3 \leq \text{MCS} < \text{MCS}_4$	Every 4 th OFDM symbol

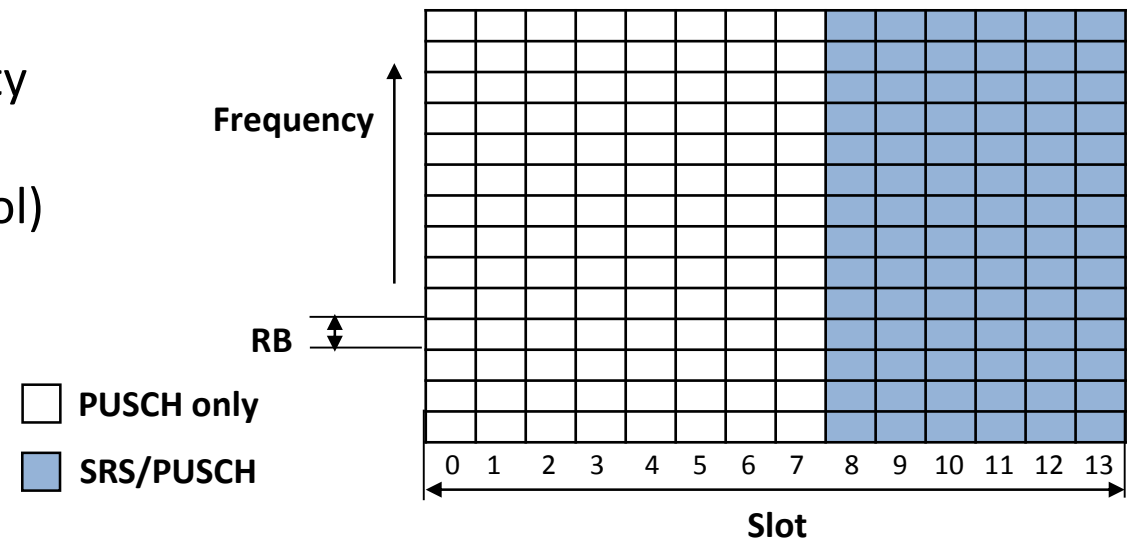


Scheduled bandwidth	Frequency domain density
$0 \leq N_{\text{RB}} < N_{\text{RB1}}$	No PTRS
$N_{\text{RB1}} \leq N_{\text{RB}} < N_{\text{RB2}}$	Every 2 nd RB
$N_{\text{RB2}} \leq N_{\text{RB}}$	Every 4 th RB



NR Reference Signals: SRS

- 📶 SRS is designed for evaluation of uplink channel quality and timing
 - 📶 Can also be used for downlink channel information when channel reciprocity is applicable
 - 📶 Three different types of SRS is supported: Periodic, aperiodic, and semi-persistent SRS (same time domain behavior as that of CSI-RS)
 - 📶 SRS carrier switching is supported for transmitting SRS over more than one carrier using a single uplink transmitter
 - 📶 Up to 6 OFDM symbols can be used for SRS transmission to increase SRS capacity compared to LTE (Rel-8 LTE supports up to 1 OFDM symbol)



Enhancements on NR-MIMO for Rel-16

- Enhancements on MU-MIMO support:
 - 📶 Specify overhead reduction, based on Type II CSI feedback, taking into account the tradeoff between performance and overhead
 - 📶 Perform study and, if needed, specify extension of Type II CSI feedback to rank >2
- Enhancements on multi-TRP/panel transmission including improved reliability and robustness with both ideal and non-ideal backhaul:
 - 📶 Specify downlink control signalling enhancement(s) for efficient support of non-coherent joint transmission
 - 📶 Perform study and, if needed, specify enhancements on uplink control signalling and/or reference signal(s) for non-coherent joint TX
 - 📶 Multi-TRP techniques for URLLC requirements are included in this WI
- Enhancements on multi-beam operation, primarily targeting FR2 operation:
 - 📶 Perform study and, if needed, specify enhancement(s) on UL and/or DL TX beam selection specified in Rel-15 to reduce latency/overhead
 - 📶 Specify UL transmit beam selection for multi-panel operation that facilitates panel-specific beam selection
 - 📶 Specify a beam failure recovery for SCell based on the beam failure recovery specified in Rel-15
 - 📶 Specify measurement and reporting of either L1-RSRQ or L1-SINR
- Perform study and make conclusion in the first RAN1 meeting after start of the WI, and if needed, specify CSI-RS and DMRS (both DL and UL) enhancement for PAPR reduction for one or multiple layers (no change on RE mapping specified in Rel-15)
- Specify enhancement to allow full power transmission in case of uplink transmission with multiple power amplifiers (assume no change on UE power class)

Thank you!

NR Architecture

Gino Masini
3GPP RAN WG3 Chairman
Ericsson



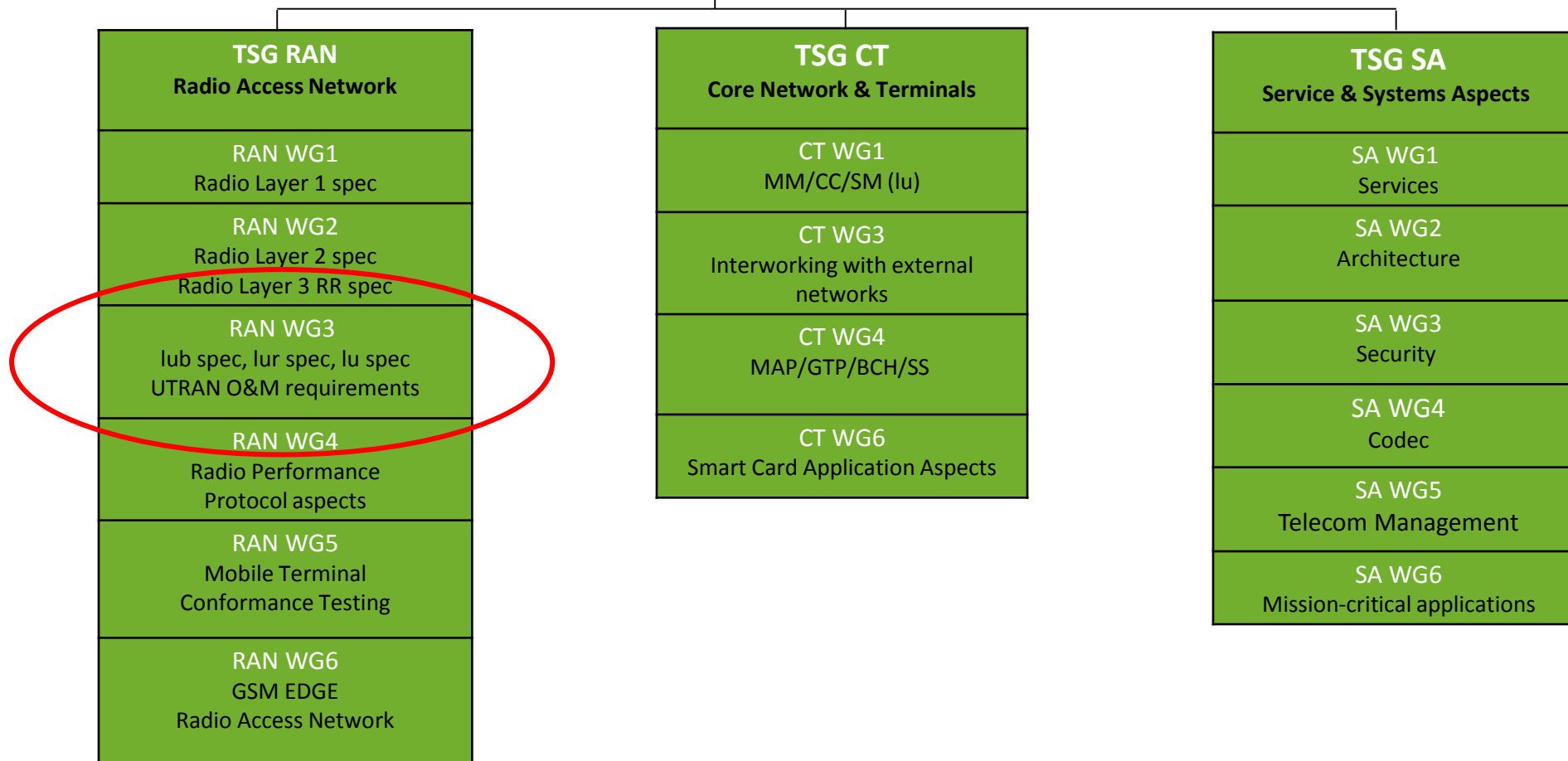
Acknowledgments

My heartfelt thanks to:

Gao Yin (ZTE) 3GPP RAN WG3 Vice-Chair

Sasha Sirotkin (Intel) 3GPP RAN WG3 Vice-Chair

Project Coordination Group (PCG)



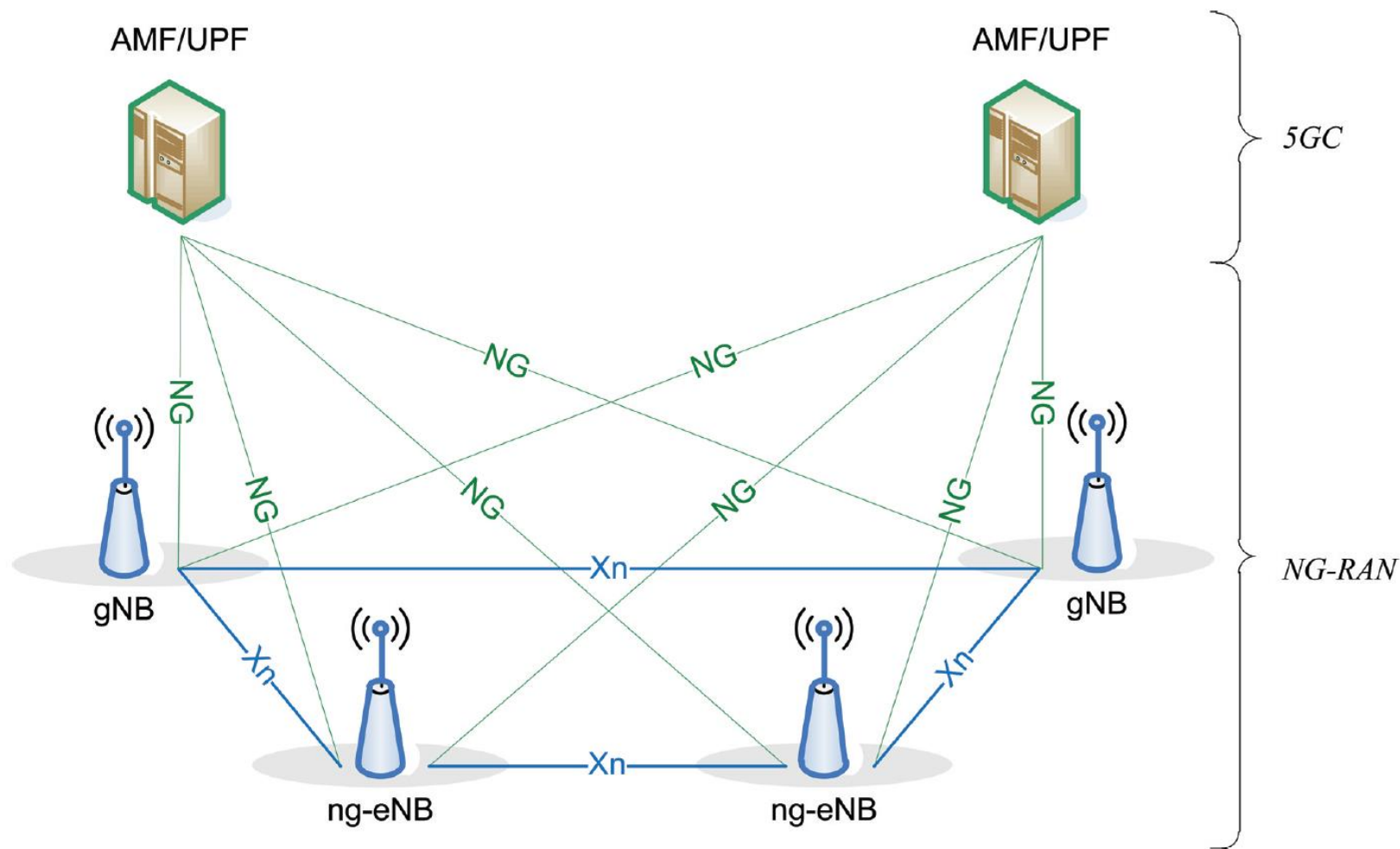
Summary

- What is NG-RAN?
- Stand-Alone (SA) and Non-Stand-Alone (NSA)
- gNB split architecture
- The unified User Plane
- gNB CP-UP split architecture
- Conclusions

What is NG-RAN?

- The New RAN (Radio Access Network) for 5G
 - 📶 Provides both NR and E-UTRA (“LTE”) radio access
- An NG-RAN node is *either*
 - 📶 **gNB** – (“5G base station”, providing NR access) *or*
 - 📶 **ng-eNB** (“enhanced 4G base station”, providing E-UTRA access)
- NG-RAN nodes are connected:
 - 📶 To the 5G core network – NG interface
 - 📶 To one another – Xn interface

The NG-RAN



Deployment Options (1)

- Both **Stand-Alone (SA)** and **Non-Stand-Alone (NSA)** deployments are possible
- Maximum flexibility for operators

Deployment Options (2)

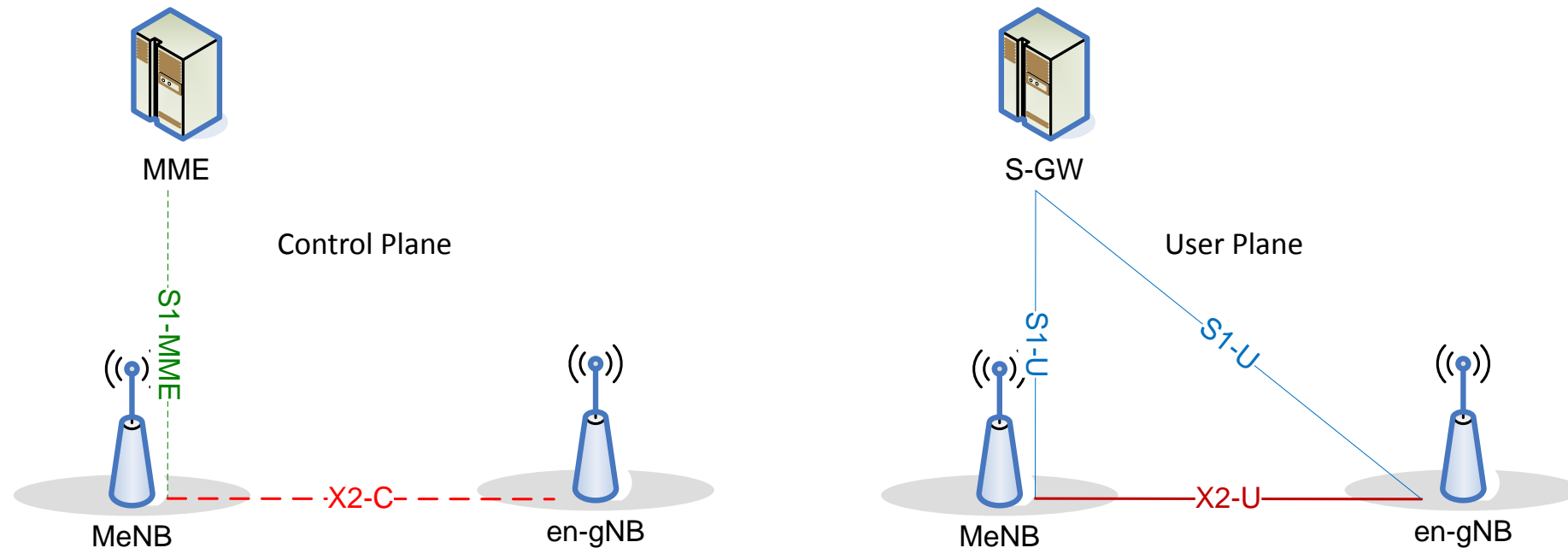
- **Stand-Alone (SA):** gNB connects to the 5G Core Network (5GC)
- **Non-Stand-Alone (NSA):** tight interoperation between gNBs and ng-eNBs
 - Connected to the same core network: *either*
 - EPC, the existing LTE core network (NSA within “4G RAN”) *or*
 - 5GC, the 5G core network (NSA within NG-RAN)
 - **Dual Connectivity (DC) toward the terminal**
 - A Master Node (MN) and a Secondary Node (SN) concurrently provide radio resources toward the user, for higher bit rate
 - The terminal “sees” a Master Cell Group (MCG) and a Secondary Cell Group (SCG)

Architecture “Options”

- Combinations of various alternatives for Master Node (MN), Secondary Node (SN), and core network types
 - (numbering is for reference only)
 - Different migration paths are possible according to operator strategy

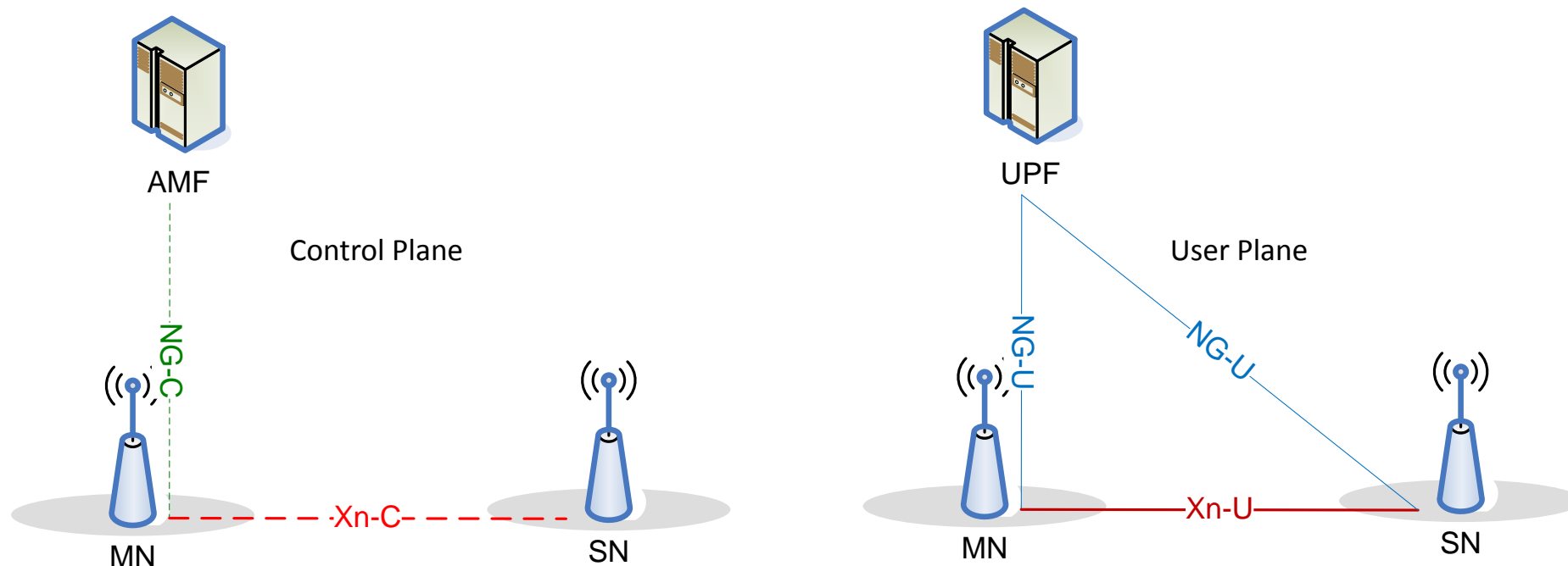
Option 3 (“EN-DC”)

- eNB as MN, connected to LTE core network
- “en-gNB” as SN
- Only a subset of 5G radio functionality is needed for this use



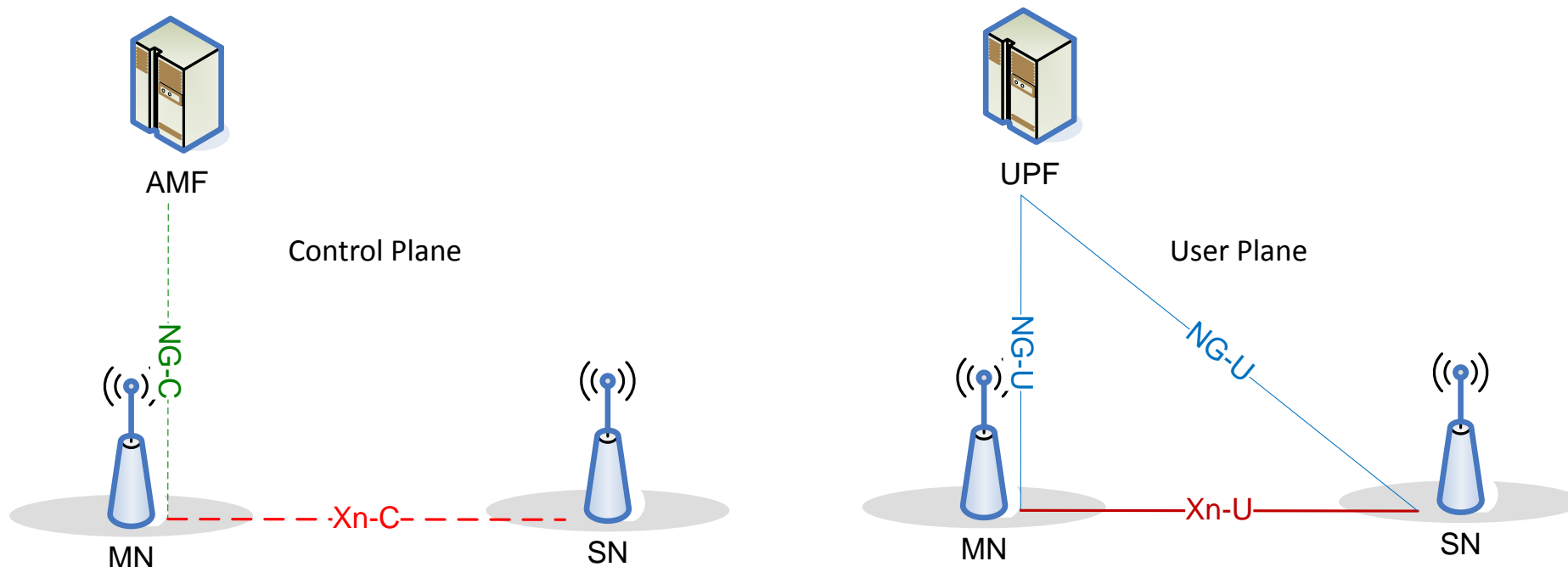
Option 4 (“NE-DC”)

- gNB as MN, connected to 5G core network
- ng-eNB as SN



Option 7 (“NGEN-DC”)

- ng-eNB as MN, connected to 5G core network
- gNB as SN



Other Available Options

- Option 2: gNB connected to 5G core network (SA operation)
 - “NR-NR DC” is supported (gNBs as MN and SN)
- Option 5: ng-eNB connected to 5G core network






Migration Considerations (1)

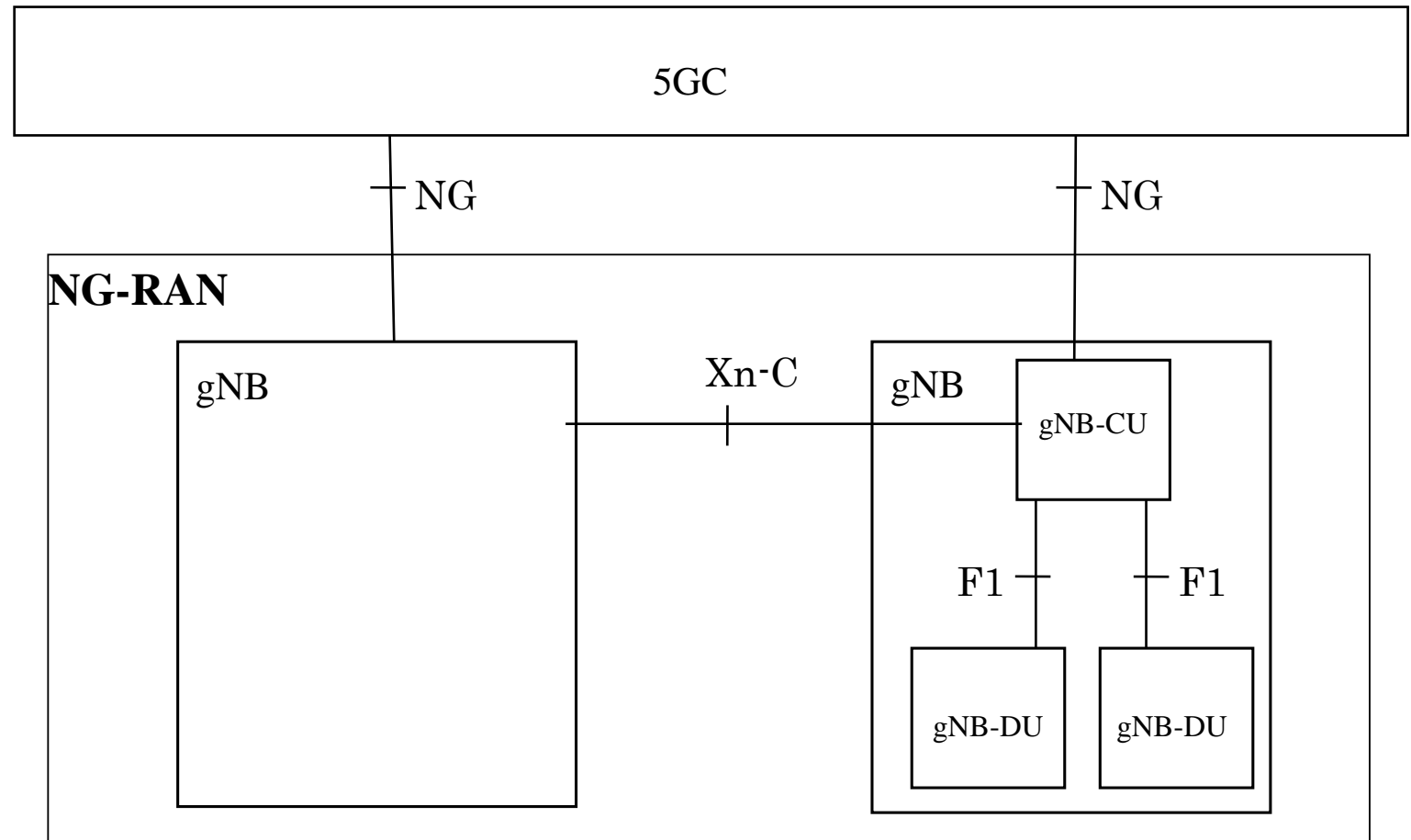
- Migration choice and path depends on:
 - 📶 Operator strategy
 - 📶 Business decision on when to deploy the 5G core network
 - Introduction of new distinctive 5G features (e.g. slicing)
 - 📶 Availability of new frequencies for NR
 - 📶 Existing network density
 - 📶 Increase of end-user traffic
 - 📶 Availability of terminals with the right feature set / bands
 - 📶 ...

Migration Considerations (2)

- If initial NR deployments use higher frequencies (e.g. above 6 GHz):
 - 📶 Smaller coverage on NR than on LTE
 - 📶 **Opt. 3** uses LTE for coverage and NR for higher capacity in busy areas, leveraging existing investments
- When 5G core network is deployed:
 - 📶 **Opt. 2** (SA) and **4** (NR for coverage, LTE as booster) use NR as basis for coverage
 - 📶 **Opt. 5** (ng-eNB for coverage) and **7** (ng-eNB for coverage, NR as booster) use LTE as basis for coverage

gNB Split Architecture

- 
 gNB may be split into a central unit (gNB-CU) and one or more distributed units (gNB-DUs)
 - 
 More deployment flexibility
 - 
 Better support for e.g. low latency services
- 
 One gNB-CU may connect to multiple gNB-DUs
- 
 One gNB-DU may support one or more cells

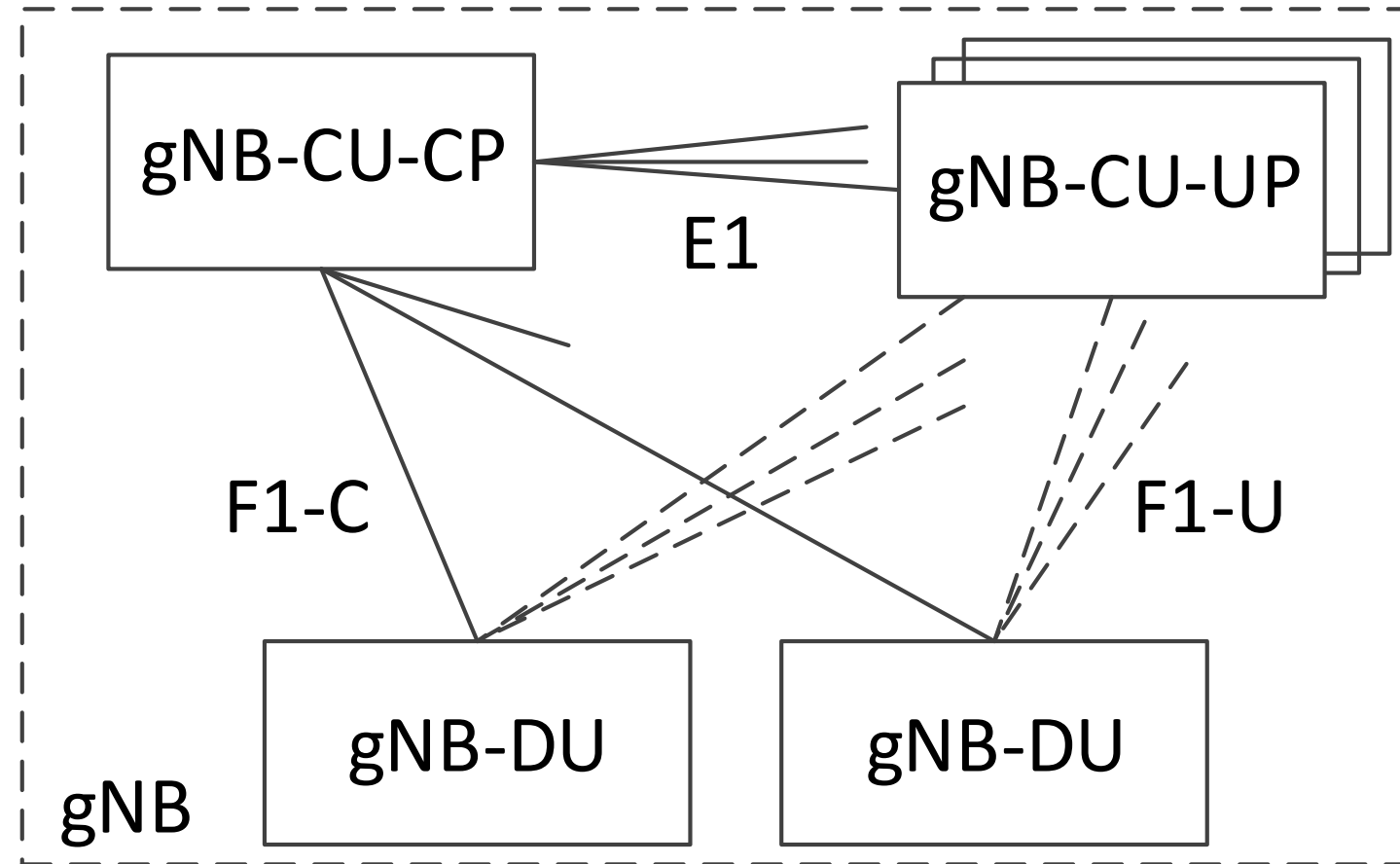


The Unified User Plane

- The same user plane protocol is used for:
 - 📶 Xn-U (between NG-RAN nodes connected to 5GC)
 - 📶 X2-U between an eNB and an en-gNB for Option 3
 - 📶 F1-U (between gNB-CU and gNB-DU)
- A single user plane instance may run all the way from the gNB-DU to another NG-RAN node
 - 📶 One “hop”, no intermediate terminations

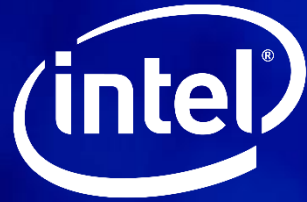
gNB CP-UP Split Architecture

- gNB-CU may be split into its control plane and user plane parts (gNB-CU-CP and gNB-CU-UP)
 - More deployment flexibility
- One gNB-CU-CP may connect to a single gNB-CU-UP
- One gNB-DU may support one or more cells



Conclusions

- NR tightly interoperates with existing LTE networks
- The NG-RAN interfaces and protocols specified by 3GPP facilitate the evolution of 4G to 5G and help the uptake of the 5G core network
- Upcoming enhancements address new requirements beyond mobile broadband
 - 📶 e.g. automated driving, industrial automation, e-health services, etc.



NR Radio interface Protocols

RWS-180010

Workshop on 3GPP submission towards IMT-2020

24-25.10.2018 in Brussels

Topics

Control plane functions and procedures

- INACTIVE state and state transition to Connected

User plane protocols

- Functions, differences to LTE with motivation

Non standalone specific functions

- Control plane architecture
- Bearer types

Rel-16 topics

RRC in NG-RAN

RRC main functions: Connection control

RRC connection control: establishment, reconfiguration and release of the RRC connection

Initial security activation, i.e. initial configuration of integrity protection and ciphering in RAN (SRBs, DRBs)

INACTIVE state management

- suspension/resumption of RRC connection

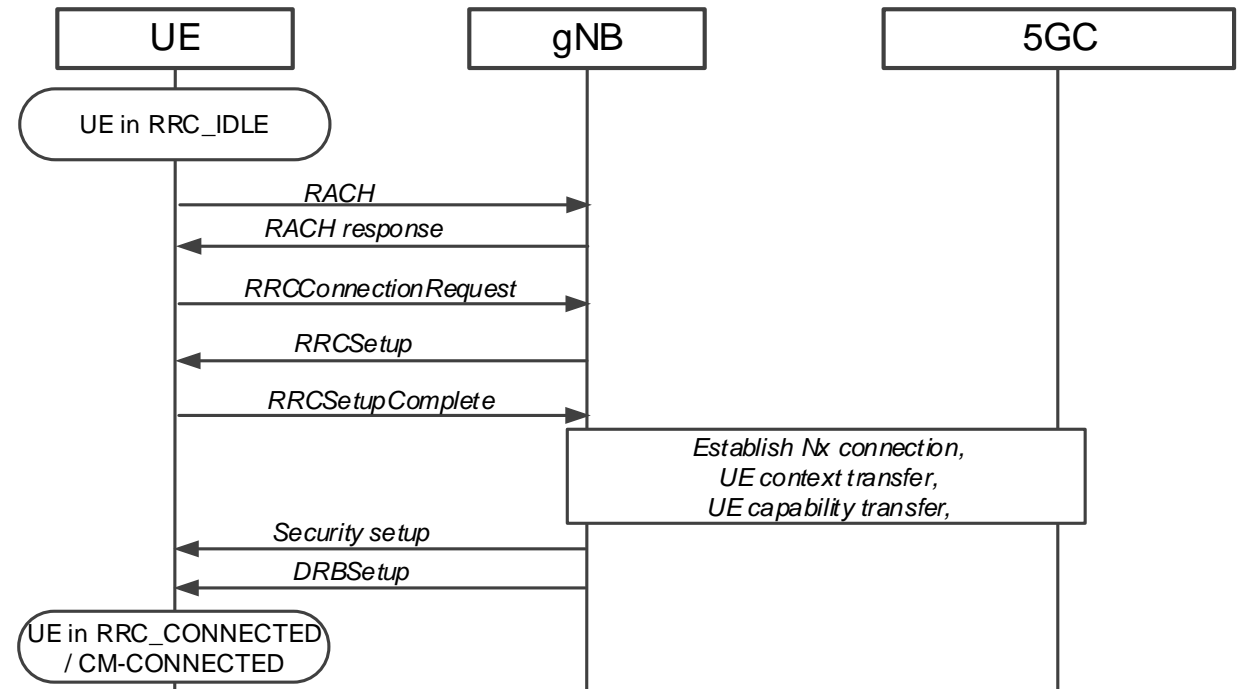
Mobility related: Handover, measurement configuration/reporting

Failure recovery

Connection establishment

Procedurally similar to LTE

- RRC connection request, setup, setup complete
- Nx connection establishment with 5GC with UE context and capability transfer
- Security configuration
- DRB setup
- Idle to connected delay different compared to LTE
 - 5GC NAS service request message design is different and larger than EPC



Security

Security establishment procedure will be the same as in LTE

Key differences:

- Integrity protection to be supported for DRB
 - Data failing Integrity protection to be discarded
- Both ciphering and integrity protection is configurable per DRB
 - Certain PDU sessions may not security
- Every handover may not need a key change
 - Change of keys expected only if there is change in Central Unit (CU) (i.e., PDCP location) for split CU/DU RAN

Mobility

Mobility procedures also similar to LTE

- No procedural changes/optimisations for Handover or inter-RAT mobility compared to LTE in Rel-15
 - Main changes are to UE measurements based on NR PHY
- Idle mode: Similar to LTE
 - Priority based mechanisms of LTE re-used
 - Applicable also for INACTIVE
 - Changes required to support NR PHY for cell reselection measurements

RRM

Overall measurement framework is similar to LTE except beam related aspects.

- Three measurement types: intra-frequency, inter-frequency, inter-RAT measurements for E-UTRA
- The association between a measurement object and a reporting configuration is created by a measurement identity
- Reference signal: SSB for idle mode; SSB and/or CSI-RS for Connected mode
- Beam level measurement and reporting
 - The UE measures multiple beams of a cell and derive the cell quality from the multiple beams
 - Measurement reports may contain beam results (beam identifier only, measurement result and beam identifier, or no beam reporting) in addition to cell quantities
- Measurement gap
 - Non-gap-assisted or gap-assisted depends on the capability of the UE, the active BWP of the UE and the current operating frequency

Slicing

- Network Slicing is a concept to allow Mobile Network Operators (MNO) to consider customers with different service requirements
- Slice selection is “similar” to PLMN sharing in terms of implementation
 - Dedicated frequency priorities (as in LTE) can be used by network to prioritise frequencies that support the slices allowed
- UE can support max 8 network slices simultaneously
- Resource management between slices: Partitioning and isolation of resources
 - Largely handled via implementation with no RAN standards impact
- No direct relationship in specifications between slicing and other vertical services such as URLLC

Other RRC functions

System information broadcast and acquisition

- On demand SI transfer – network does not always have to broadcast SI, saves network energy and resources

Access class barring and overload handling

- Unified Access Control mechanism different from LTE, providing similar functionality

Paging similar to LTE

- Paging occasion calculation formula updated to consider NR PHY and is S-TMSI based

Positioning

- UE operating in NR can obtain position using LTE signals and RAT independent methods
- No support for native NR methods in Rel-15 other than E-Cellid

UE capability transfer

- Similar to LTE with storage in AMF

ANR/SON (but no MDT in Rel-15)

RRC INACTIVE (new state)

Motivation of the new RRC_INACTIVE state

Significant delay reduction in INACTIVE to CONNECTED compared to IDLE to CONNECTED

Reduce the signalling overhead (on radio and network interfaces), enabling UE power consumption similar to IDLE while improving the UE access latency

Key aspects:

- UE context storage in RAN during INACTIVE
 - UE context stores both 5GC information including security and UE radio configurations
 - allowing transitions between INACTIVE and CONNECTED without involving Core Network
 - UE centric mobility, e.g. cell (re)-selection in INACTIVE
 - Transitions between Inactive and Connected, and mobility while in Inactive are hidden from CN

State transitions

INACTIVE → CONNECTED

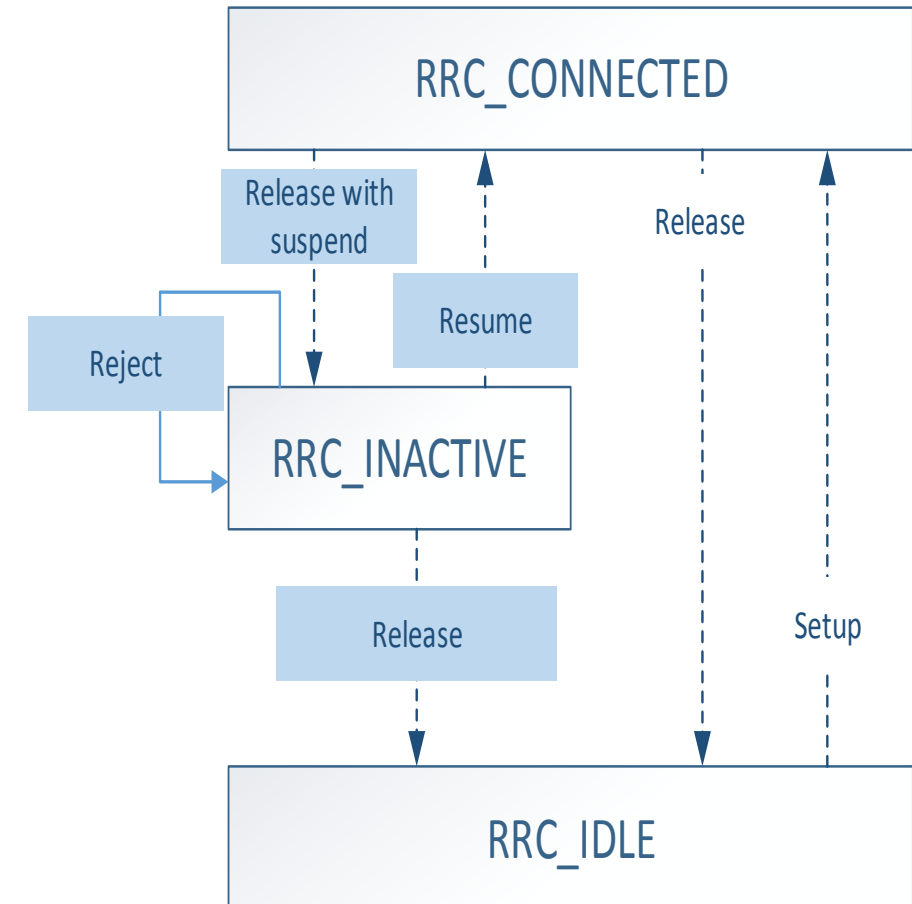
- 3-step RRC procedure

CONNECTED → INACTIVE

- 1-step RRC procedure

INACTIVE → IDLE

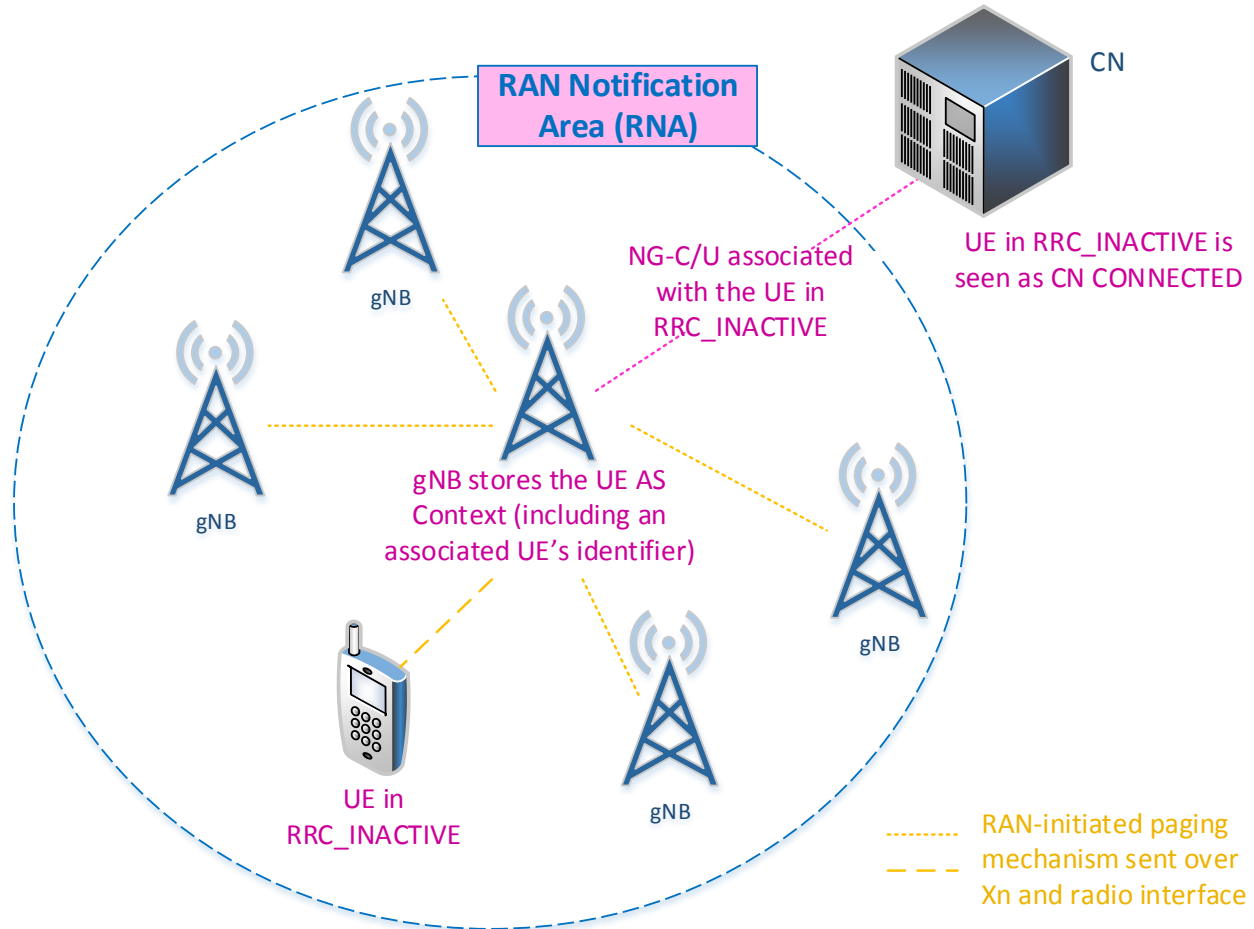
- 2-step RRC procedure for RNAU (request/release)
- Autonomously by UE:
 - Upon reception of CN initiating paging
 - Upon reselecting to other RAT



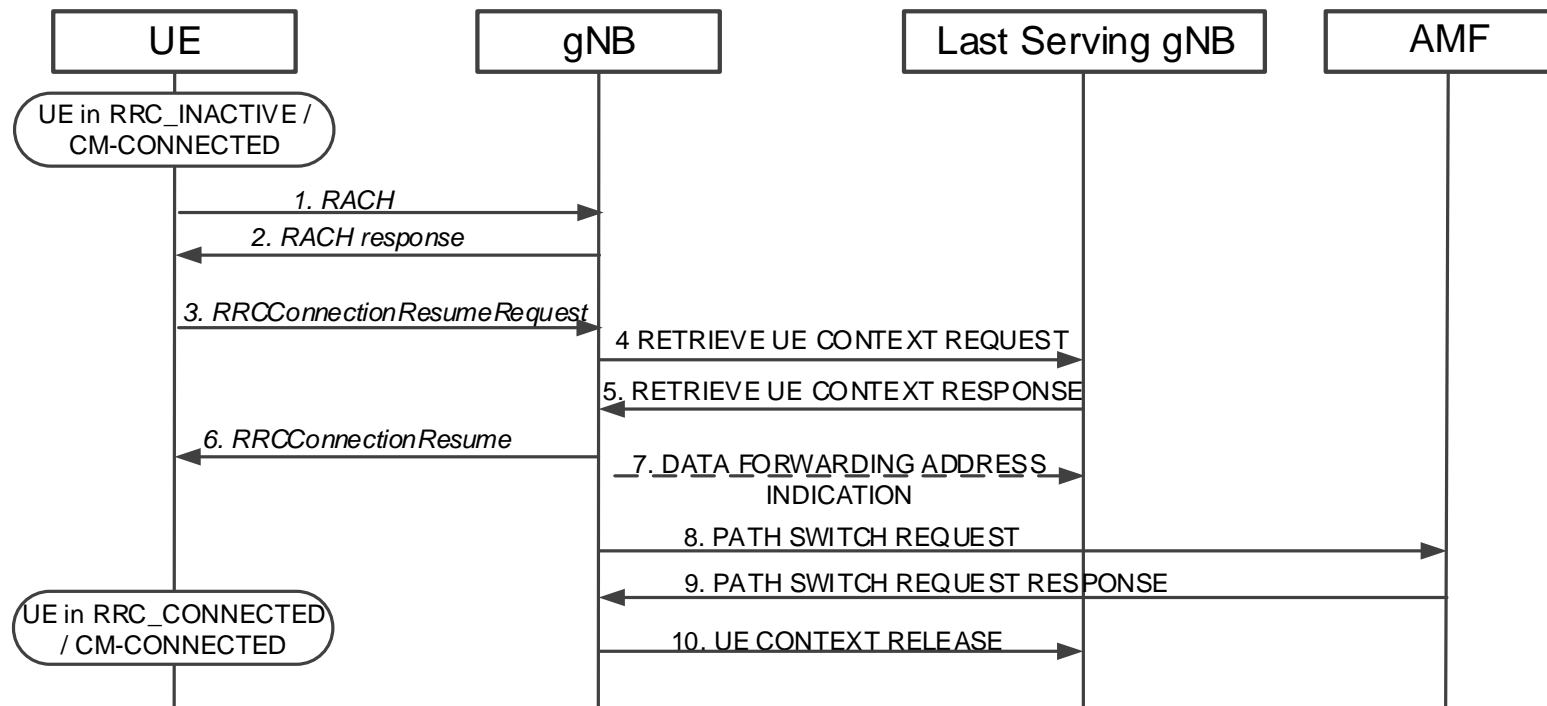
RAN-initiated paging, RAN Notification Area (RNA) and RAN Notification Area Update (RNAU)

RRC_INACTIVE is characterized by

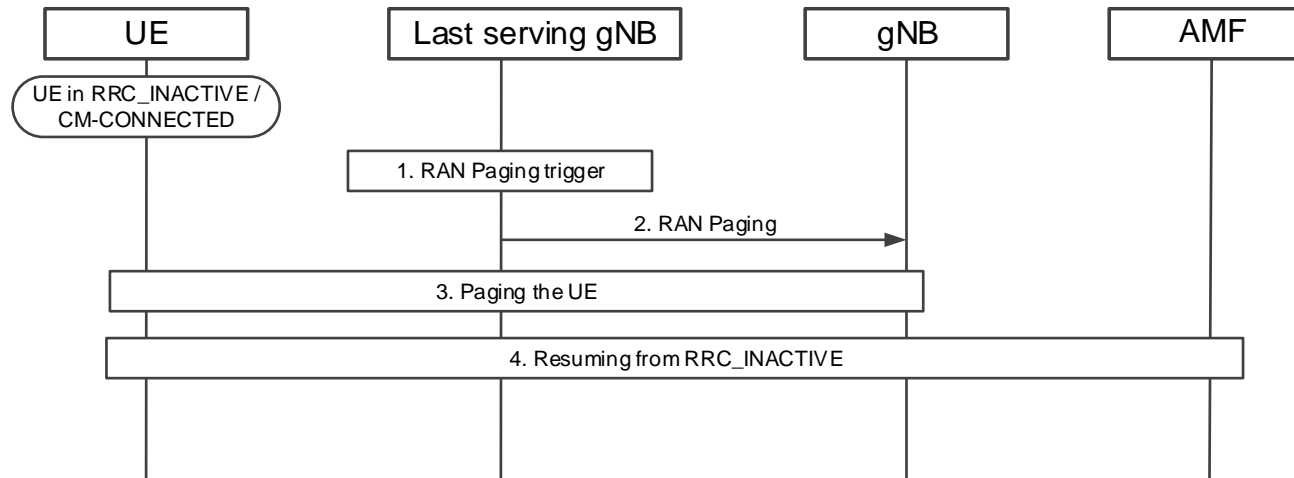
- Use of RAN Notification area (RNA) for INACTIVE
 - similar to CN tracking area for Idle
- RNA is configured per UE by gNB
 - 1 to N cells defined by a *List of cells or list of RAN Area ID or list of TA IDs*
- UE is reachable within a configured RNA via a RAN-initiated paging
 - *RAN-initiated paging uses a RAN configured UE ID (I-RNTI)*
- RNAU triggered periodically and when moving outside of the configured RNA



UE triggered transition from RRC_INACTIVE to RRC_CONNECTED



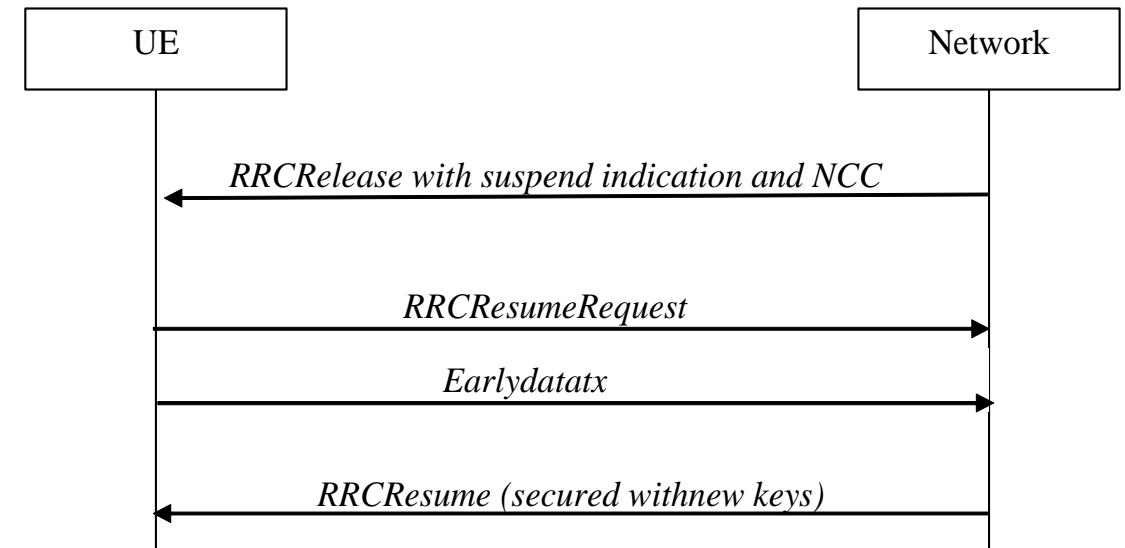
Network triggered transition from RRC_INACTIVE to RRC_CONNECTED



Security handling: forward compatibility for Early data transmission

“New key” (NCC) provided to UE when UE is suspended to be used at next Resume

- Forward compatibility for Early data transmission
 - Possibility to introduce mechanism to send encrypted data using new key immediately after ResumeRequest
 - May be discussed in later release
- msg 4 (Resume) can be encrypted to carry RRC reconfiguration information avoiding multi step reconfiguration

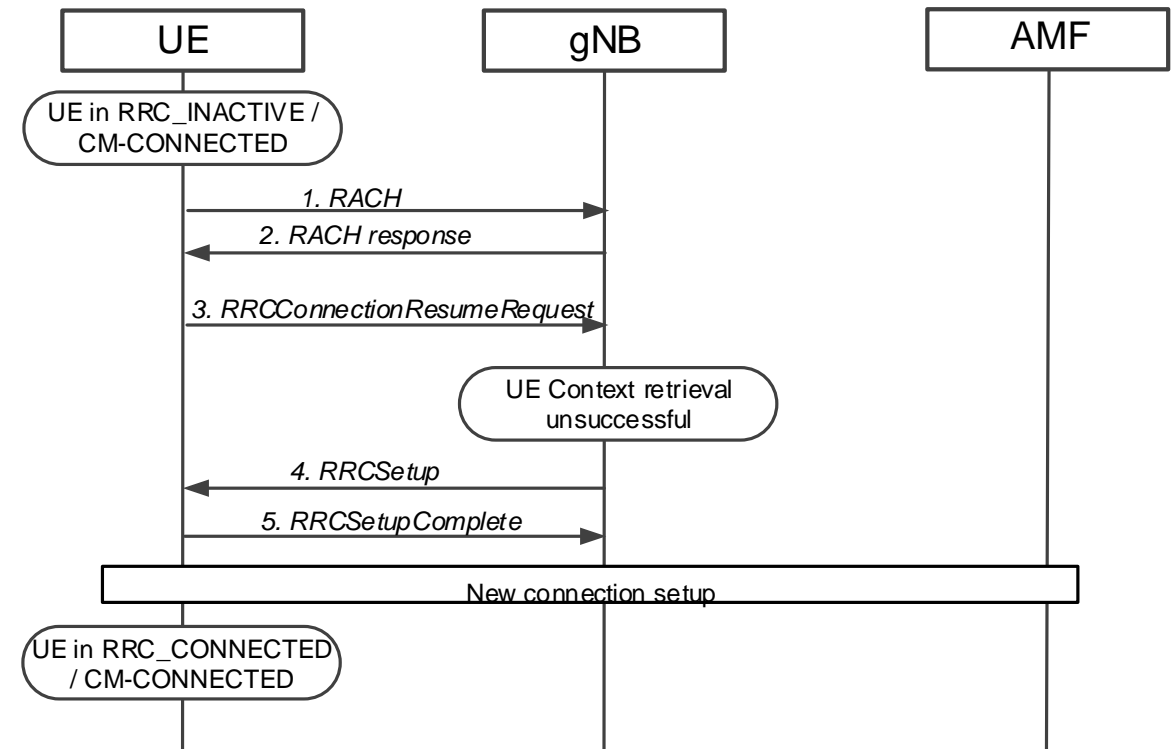


“Fallback” to connection establishment

Fallback for quick recovery in case network cannot resume UE

- E.g., if the RAN cannot retrieve UE context
- Direct step from Resume request to Setup
 - Avoids another RACH access compared to new Connection Request

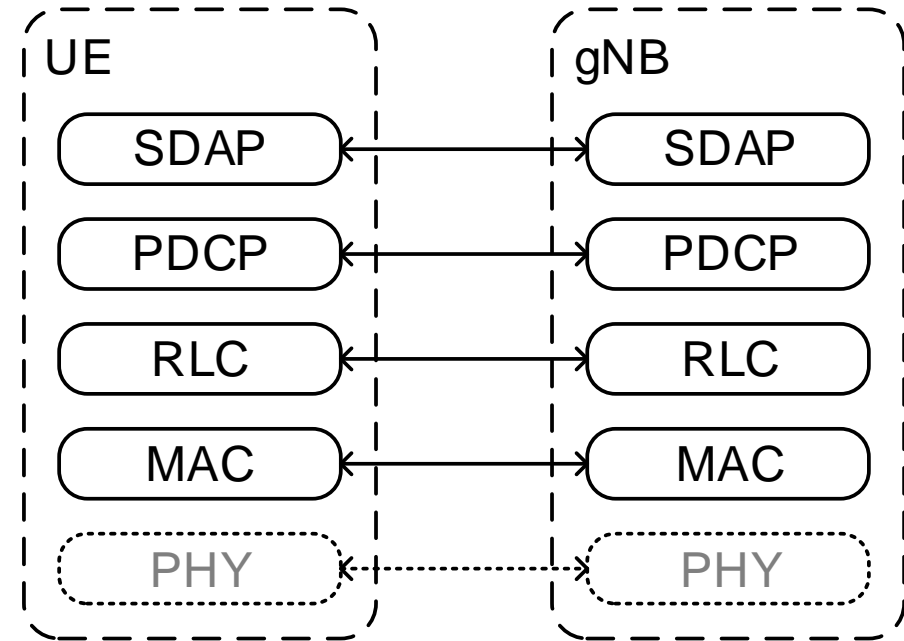
Can also be used with re-establishment



User plane and 5G QoS

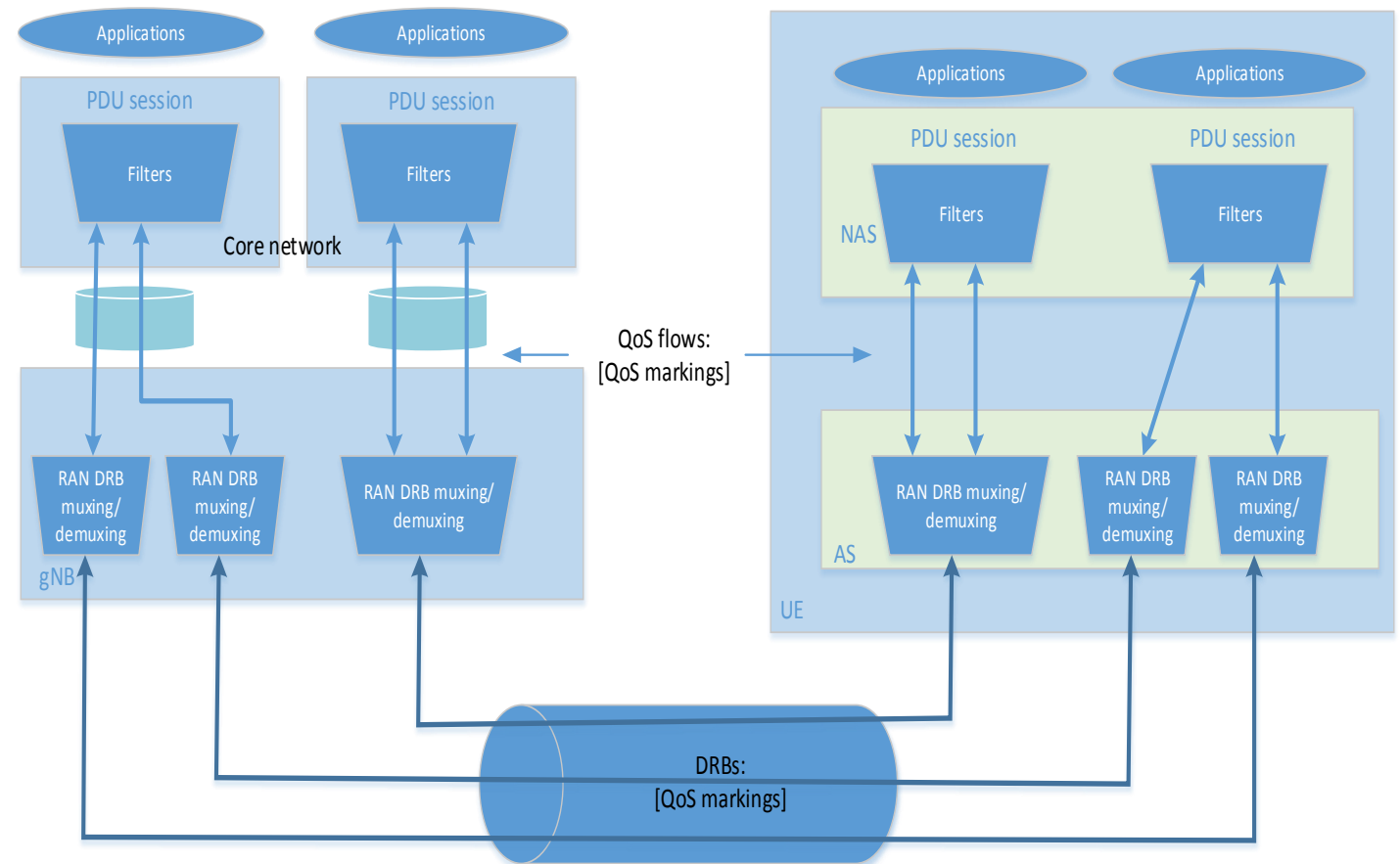
User plane protocol stack - overview

- NR PDCP, RLC and MAC are all new protocols but share many similarities with corresponding LTE protocols
- SDAP protocol introduced to support new flow based QoS model of the 5GC



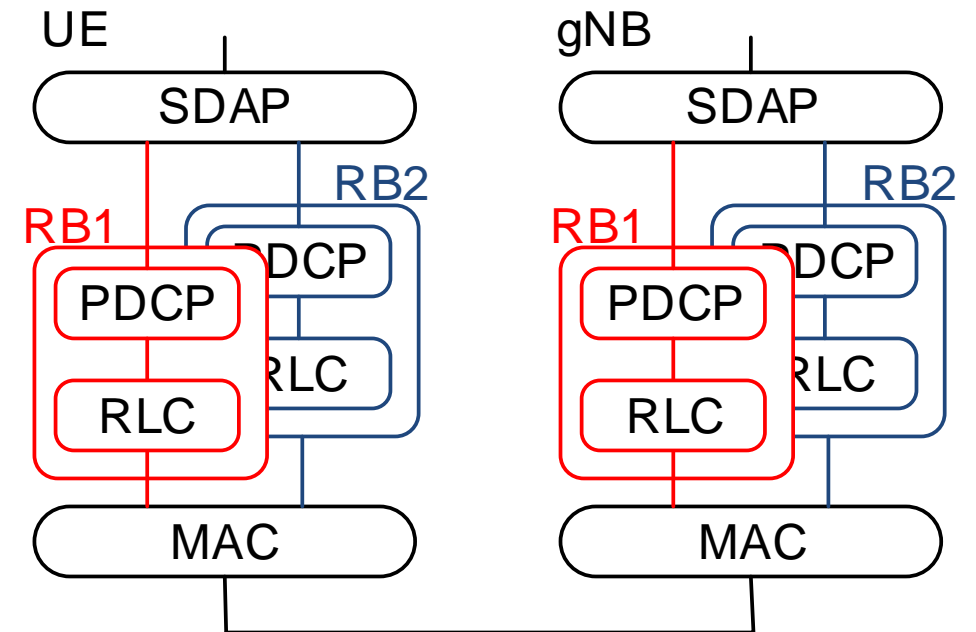
New QoS model for 5GC

- QoS flow based marking in Core Network instead of EPS bearers to differentiate QoS “streams” in a PDU session
- RAN continue to use DRBs
 - All packets in a DRB will receive same QoS treatment
- Mapping of QoS flow to DRB is left to gNB implementation (new concept)
 - Results in two step mapping:
 - IP to QoS flow in NAS
 - QoS flow to DRB in AS



Service Data Adaptation Protocol (SDAP)

- 5G CN and upper layers in the UE mark packets for transmission with a QoS flow identifier (QFI)
- Each QFI associated with different QoS in terms of delay, reliability, etc
- SDAP layer maps QoS flows to radio bearers, with PDCP/RLC of each RB configured appropriately for the QoS
- MAC layer gives differentiated handling (e.g. priority) to traffic from different RBs
- gNB has flexibility how to achieve the QoS



SDAP - Reflective mapping of QFI to radio bearer

- The mapping from QFI to radio bearer is controlled by the gNB in 2 ways:
- RRC configuration signalling
- Reflective mapping
 - A QFI is transmitted in the UL on the same radio bearer as that QFI was received in DL
 - Enable changing QFI to radio bearer mapping in a more dynamic way and with lower signalling overhead

Packet Data Convergence Protocol (PDCP)

Header compression/decompression through the use of RoHC

Ciphering and integrity protection

- Key difference compared to LTE PDCP is that integrity protection can be applied to user plane traffic as well as control plane signalling

Data duplication

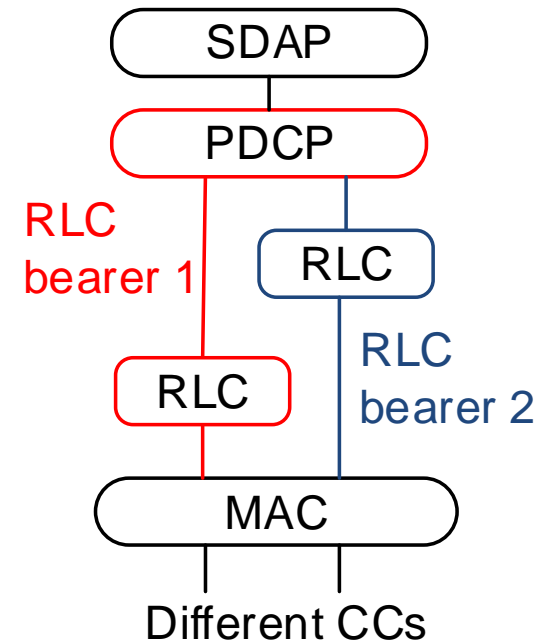
- Key new feature compared to LTE PDCP

Duplication detection and reordering of received PDPC PDUs

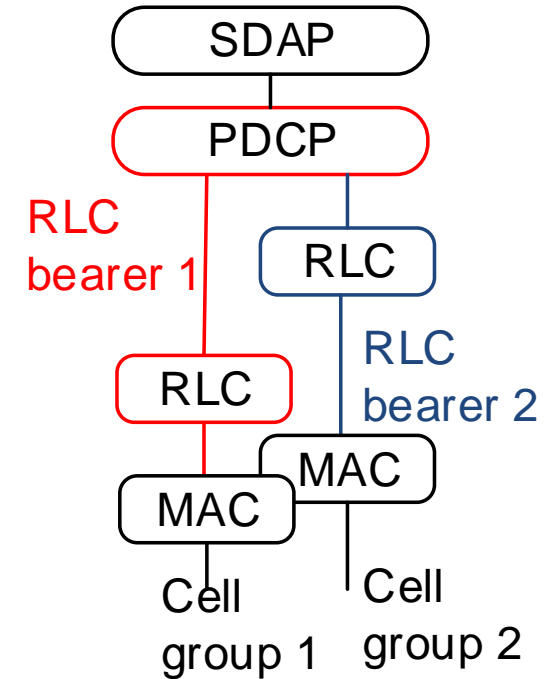
PDCP - Data duplication

- PDCP PDUs can be duplicated for transmission over 2 RLC bearers
- Motivated to enable the reliability/delay requirements for URLLC applications
- In case of carrier aggregation (CA)
 - Restrictions configured in the MAC ensure that duplicated data is transmitted via different component carriers
- In case of dual connectivity (DC)
 - RLC bearers are mapped to different cell groups (i.e. MCG and SCG)

Duplication - CA case



Duplication - DC case



Radio Link Control Protocol (RLC)

Similar functionality compared to LTE RLC:

- Segmentation to match the transmitted PDU size to the available radio resources
- Error correction through ARQ

Key differences compared to LTE RLC:

- Does not provide concatenation of RLC SDUs
 - Equivalent functionality now provided by the MAC layer. Motivated to enable UL RLC PDUs to be pre processed within the UE before reception of UL grant.
- Does not provide reordering of received RLC SDUs
 - Equivalent functionality now provided by the PDCP layer

Medium Access Control (MAC)

- Similar functionality compared to LTE MAC:
 - Multiplexing and demultiplexing of data from different radio bearers to the transport blocks that are carried by the physical layer
 - Priority handling between data from different radio bearers
 - Error correction through Hybrid ARQ.
 - Discontinuous reception (DRX)
- Key differences compared to LTE MAC
 - Functionality to support beam based operation for high frequent operation.
 - More flexible UL configured grants
 - MAC PDU format optimised to enable pre-processing and facilitate low delay

MAC - Support of beam based operation

- Beam failure detection and recovery
 - UE Phy layer monitors beam failure detection (BFD) reference signals to determine a beam failure
 - On beam failure detection the UE MAC layer initiates beam failure recovery
 - Selects a suitable beam on which to attempt recovery
 - Performs random access procedure
- Beam management
 - Mobility between beams is performed by a combination of Phy and MAC signalling
 - RRC signalling involved only to provide a measurement configuration (e.g. configuration of the reference signals to be measured, etc)

MAC - UL configured grants

2 types of UL configured grants are available:

- Type 1 - the configured UL grant and periodicity is configured by RRC signalling
- Type 2 - the configured UL grant is provided by Phy signalling (PDCCH) and periodicity is configured by RRC signalling (similar to UL SPS in LTE)

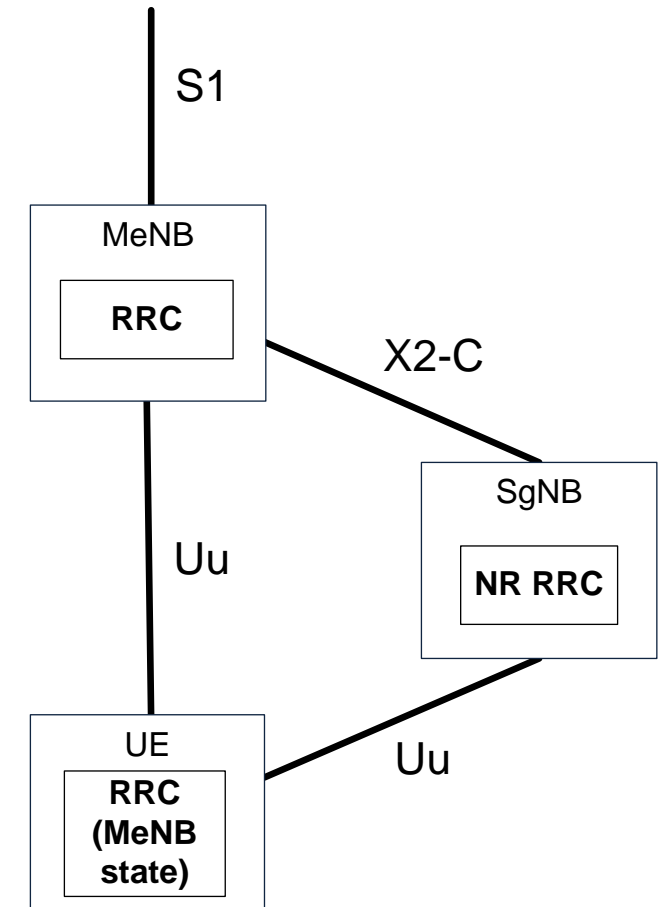
In DL, Semi-Persistent Scheduling (very similar to LTE SPS) is supported

Control plane for EN-DC

Non-Standalone: overall architecture

Dual connectivity:

- Master Node (MN):
 - Overall master, responsible for connection establishment with UE, connection to Core network, handover etc.
 - Master Cell Group (MCG) for UE
 - For EN-DC, MN is an LTE eNB
- Secondary Node (SN)
 - Secondary Cell Group (SCG) for UE
 - For EN-DC, SN is an NR gNB



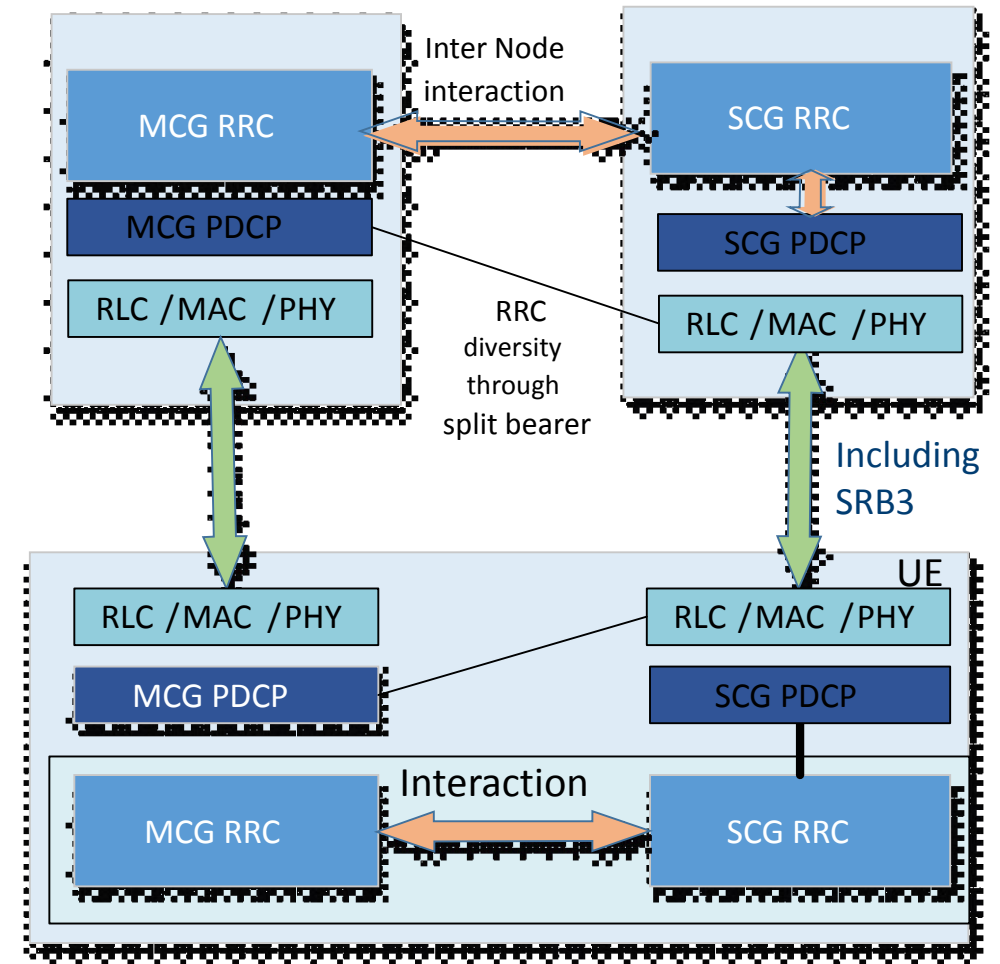
Non-standalone: Control plane for EN-DC

Single RRC state machine and control plane connection to CN based at MCG

Network has two RRC entities (MCG and SCG) that can generate full RRC messages

- RRC messages generated by the secondary can be transported transparently by the master (at least in some cases, e.g. for first configuration)

Direct RRC messages from SCG over NR – SCG SRB (SRB3)



SRB3: SCG SRB

- A new direct SRB between SeNB and UE – SRB3
 - Motivation:
 - Lower signalling delay over direct NR interface – no Xn delay and faster NR radio
 - Less processing at MN
 - Can only be used for messages that do not need coordination between MN and SN
- Can be configured based on SN decision.
 - The following RRC messages can be sent via the SRB in the SCG
 - RRCConnectionReconfiguration, RRCConnectionReconfigurationComplete, MeasurementReport
 - SCG SRB is of higher scheduling priority than all DRBs
- UE still processes one message at a time in sequence irrespective of the path the message is received in

Sub architecture options (3, 3a, 3x) and Bearer

Different bearer types based on:

- Bearer termination point of the CN interface; and
- Radio interface used for data transfer

Single UE may be configured with different bearer types

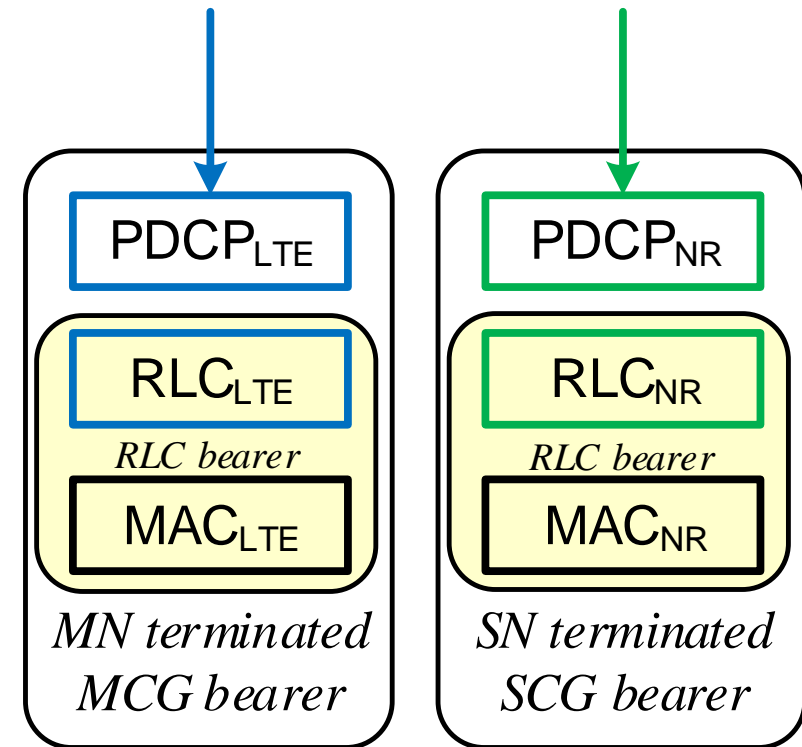
MN terminated and SN terminated bearer types

- Indicates where the data from core network for that bearer terminates in RAN
 - Also indicates the location of SDAP (for 5GC) and PDCP entities in the network for this bearer
 - E.g., MN terminated bearer implies all the data to and from CN for this bearer is through MN
- Does not imply anything about which radio interface is used for this bearer

MCG And SCG bearer

Indicates which radio interface is used to data for this bearer

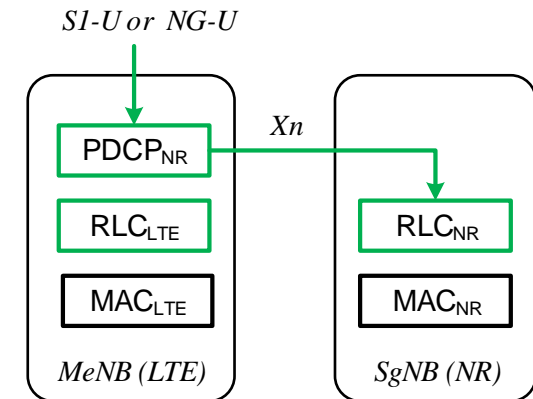
- MCG bearer implies all the data for this bearer is sent only over MCG radio interface
 - RLC bearer (RLC +MAC logical channel) in MCG
- SCG bearer implies all the data for this bearer is sent only over SCG radio interface
 - RLC bearer in SCG
- Figure shows MN terminated MCG bearer (option 3) and SN terminated SCG bearer (option 3a)



MN terminated split bearer (option 3)

Split bearer:

- Indicates both MN and SN RLC bearers are configured for this bearer
- DL data can be sent over both
- UL data can be configured to be sent over
 - Either one of the two UL; or
 - Split over both paths; or
 - Duplicated over both paths



SN terminated split bearer (option 3x)

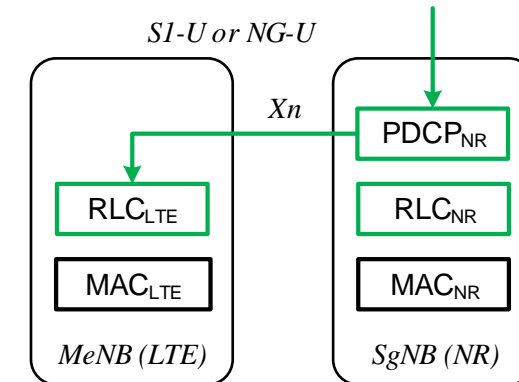
Split bearer as before

CN connection for data transfer is over SN

New option introduced for EN-DC

Allows more flexible network implementation without impacting LTE eNB hardware

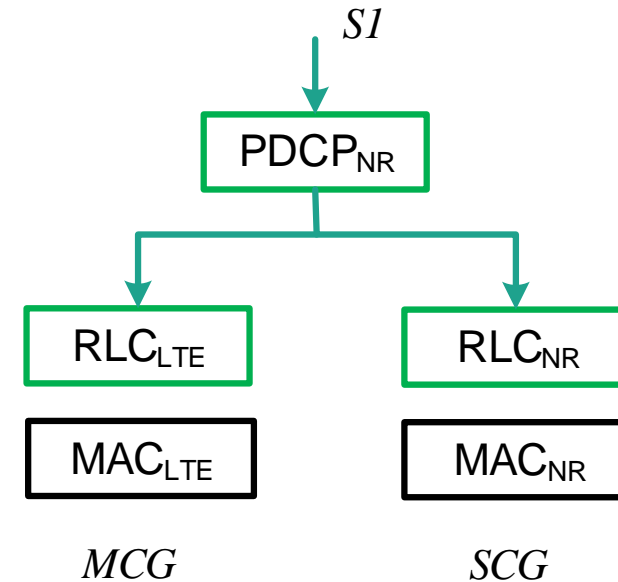
- All PDCP processing in SN for this bearer



Unified bearer at UE

A unified split bearer concept at UE

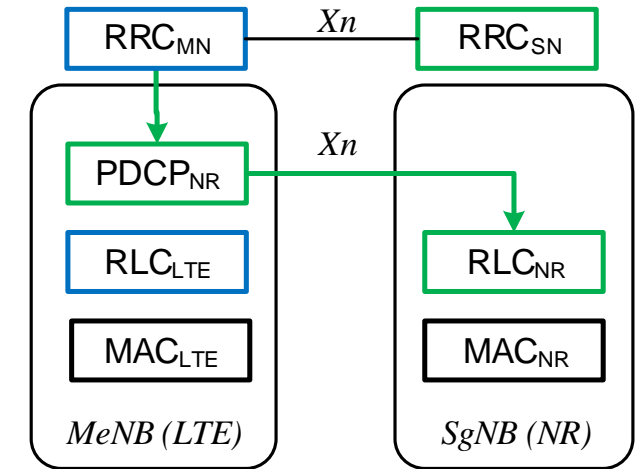
- Agnostic of the PDCP location (termination point)
 - common behaviour at the UE
- Supports MCG/SCG or both RLC bearers for a PDCP entity
- Change of bearer type is simple – by adding or removing RLC bearers



Split MCG SRBs

Similar to split DRB but for MCG SRBs (SRB1 and SRB2)

- MCG signalling reliability, especially during HO
 - But only relevant if there happens to be an SN at MN cell border



For DL, selection of transmission path depends on network implementation

UL packet transmission is configured by RRC to use MCG path, or duplicate on both MCG and SCG

Duplication and duplicate detection functions in PDCP

Other MR-DC architectures

Other architectural options to be completed by Dec 2018 in Rel-15 late drop

- NG-EN-DC: EN-DC with 5GC
- NR-DC: NR NR Dual connectivity
- NE-DC: NR is master and LTE as secondary node

Based on EN-DC architecture

- Main differences:
 - NR-DC coordination and capability handling
 - Small changes Security requirements from integrity protection of DRBs

Release 16

Release 16 work programme (1)

3GPP will continue to evolve NR functionality in Release 16 (due for completion in Q4 19) and beyond.

These slides provide very brief overview of the Release 16 work items led by 3GPP RAN working group 2 (working group responsibility for radio interface protocols)

There is other work led by other working groups e.g:

- NR in unlicensed spectrum (NR-U), NR V2X, NR positioning, NR for non terrestrial networks, etc

Release 16 work programme (1)

Integrated Access and Backhaul (IAB)

- Currently in a study phase
- Investigating the architecture and radio protocols impacts to introduce relaying where NR radio interface is also used on the backhaul links to/from the relay nodes
- Motivated by the desire to enable very dense deployment for NR cells while minimising costs associated with the backhaul network
- Aiming to support multi-hop relaying

Enhancements for Industrial IoT

- Currently in study phase
- Main focus of work is the introduction of support for Time Sensitive Networking (TSN) including provision of accurate time reference, Ethernet header compression

Release 16 work programme (2)

NR mobility enhancements

- Work due to start in Q1 19
- Aiming to provide enhancements for handover interruption time and reliability

NR dual connectivity and carrier aggregation enhancements

- Work due to start in Q1 19
- Aiming to provide various enhancement to CA/DC operation including faster measurement reporting of candidate cells and faster activation of CA and/or DC

Optimisations on UE radio capability signalling

- Currently in study phase
- Investigating mechanisms to reduce the overhead of UE capability signalling

Summary

Summary

RRC: Control plane functions and procedures

- INACTIVE state and message flow for transitions to RRC_Connected

User plane protocols

- SDAP and 5G QoS
- PDCP and packet duplication
- RLC functions with optimisation for UE implementation
- MAC functions and enhancements for NR

Non standalone specific functions

- MN and SN, RRC structure, SRB3
- Bearer types and unified bearer in the UE

Rel-16 topics: IAB, IIoT, Mobility, CA/DC enhancements, UE capability transfer optimisation

Backup

Terminology

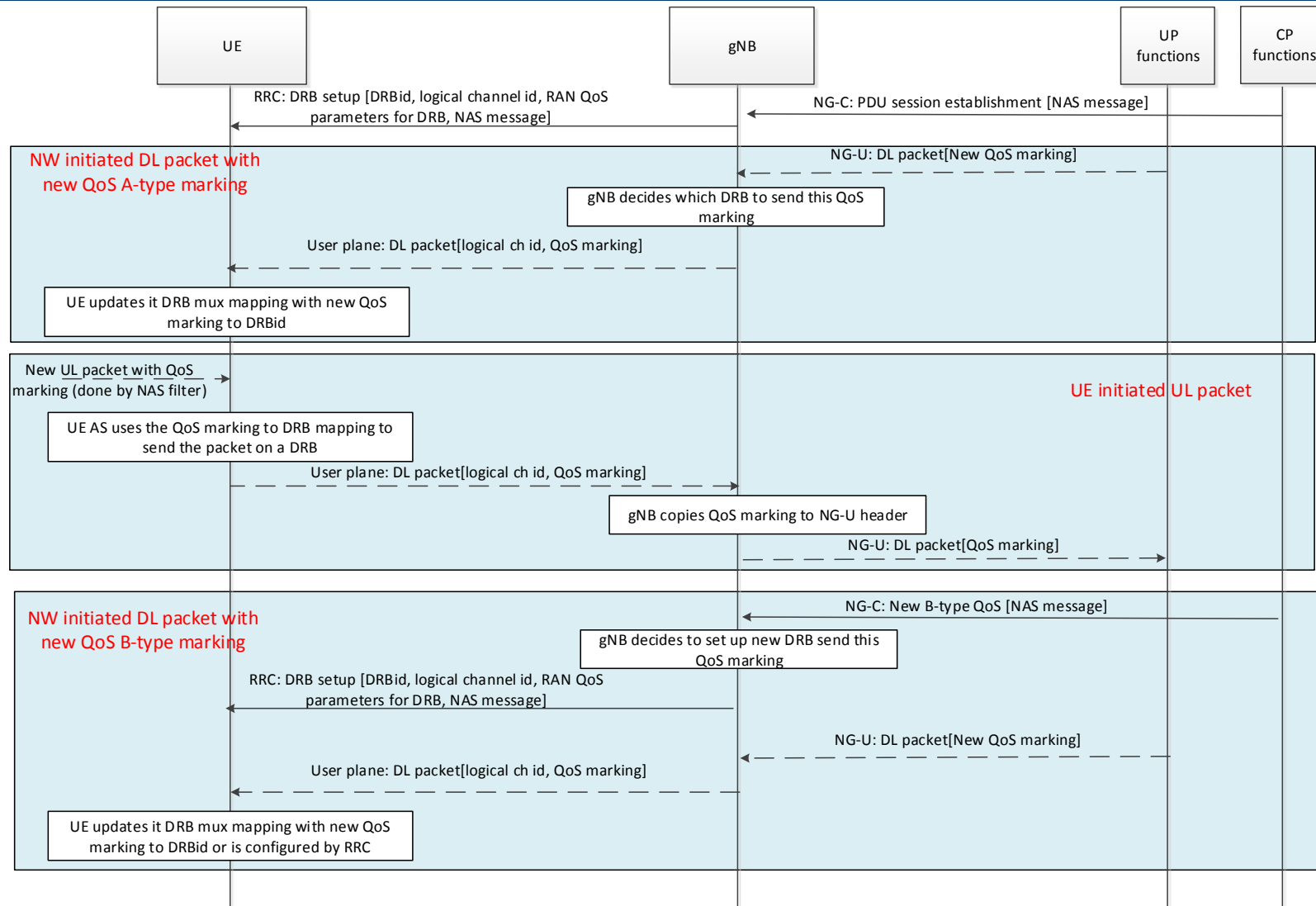
- NR Name of the Radio Access Technology (equivalent to E-UTRA).
- NG-RANRAN that connects to 5GC
 - Could use either the NR or E-UTRA radio access technology
 - Note NG-RAN is defined by its connectivity to the 5GC and not by the radio it uses.
- gNB Node B that used the NR Radio Access Technology
 - en-gNB - Node B that uses NR for E-UTRA-NR Dual connectivity. You might see this but not expected to be commonly used in RAN2 specs (more in RAN3 specs)
- NR, NG - are 'monolithic' terms - they do not stand for anything!
- 5G Marketing name and logo for 3GPP Rel-15 specs related to NR
 - Others in the industry may use '5G' in different ways



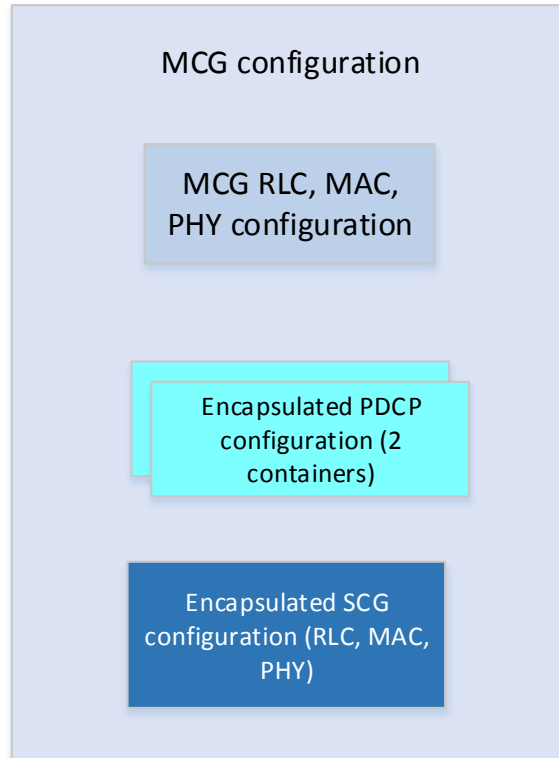
Characteristics of RRC states

RRC_IDLE	RRC_INACTIVE	RRC_CONNECTED
UE controlled mobility based on network configuration (cell reselection)		Network controlled mobility within NR and to/from E-UTRAN
DRX configured by NAS	DRX configured by NAS or gNB	DRX configured by gNB
Broadcast of system information		Neighbour cell measurements
Paging (CN-initiated)	Paging (CN-initiated or NG-RAN-initiated)	Network can transmit and/or receive data to/from UE
UE has an CN ID that uniquely identifies it w/in a tracking area	NG-RAN knows the RNA which the UE belongs to	NG-RAN knows the cell which the UE belongs to
No RRC context stored in gNB	UE and NG RAN have the UE AS context stored, and the 5GC - NG-RAN connection (both C/U-planes) is established for UE	

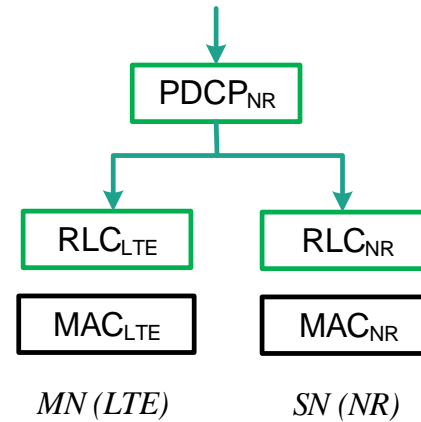
Signalling flow and use of reflective QoS in RAN and CN



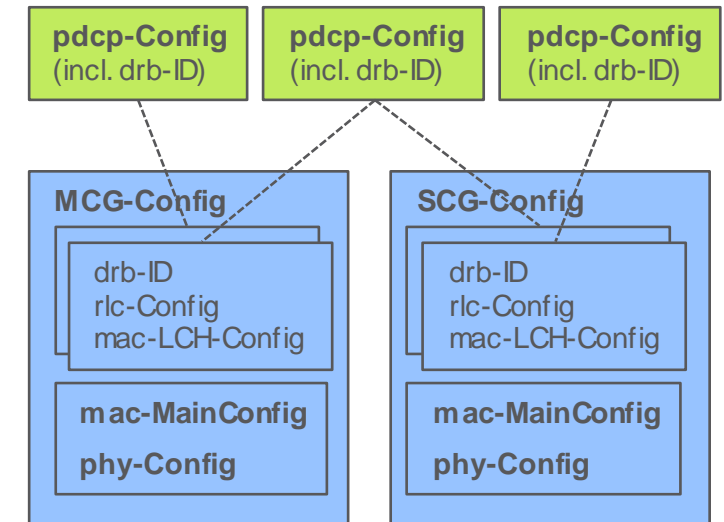
RRC message for unified bearer type



Overall RRC message structure

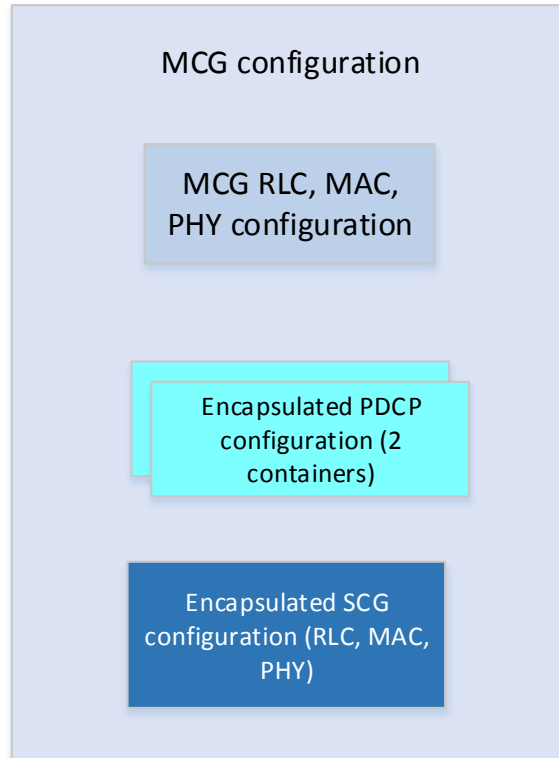


A split bearer

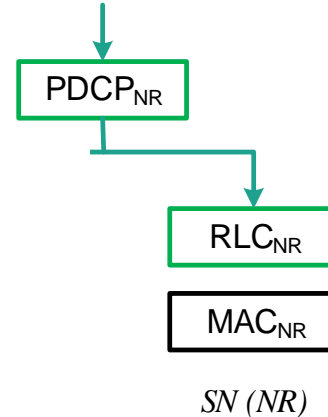


RRC configuration structure of the user plane for multiple bearers (FFS)

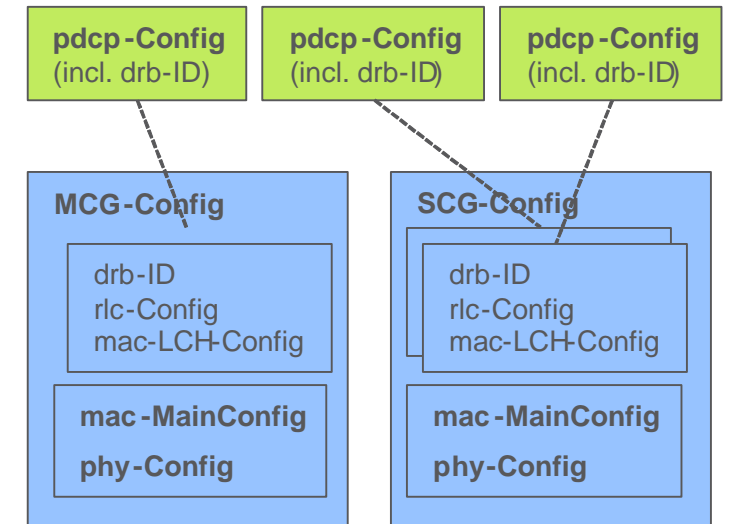
RRC message for unified bearer type



Overall RRC message structure

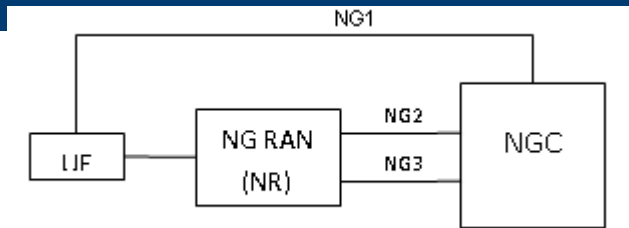


A split bearer configured as SCG bearer

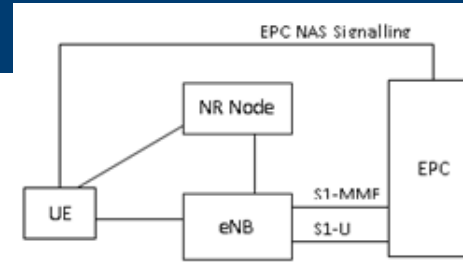


RRC configuration structure of the user plane when configured as SCG bearer

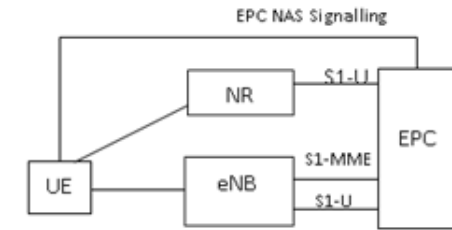
Deployment Options



Option 2 – NR Standalone

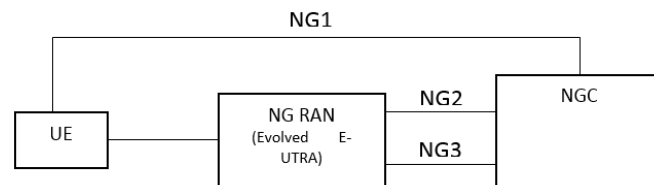


(3a)

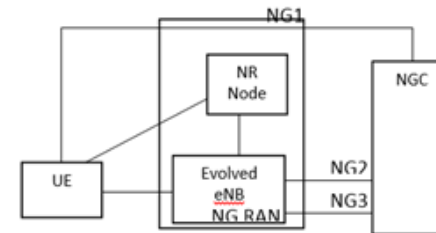


(3a1)

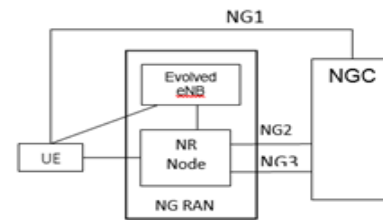
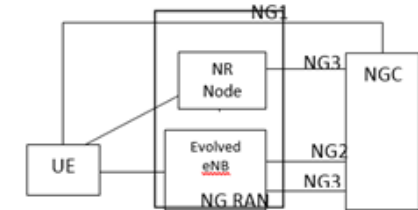
Option 3 – Non Standalone (EN-DC)



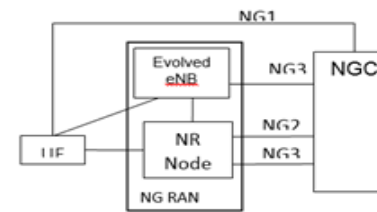
Option 5 – Evolved E-UTRA standalone



Option 7 – NSA with NG Core (NG-EN-DC)

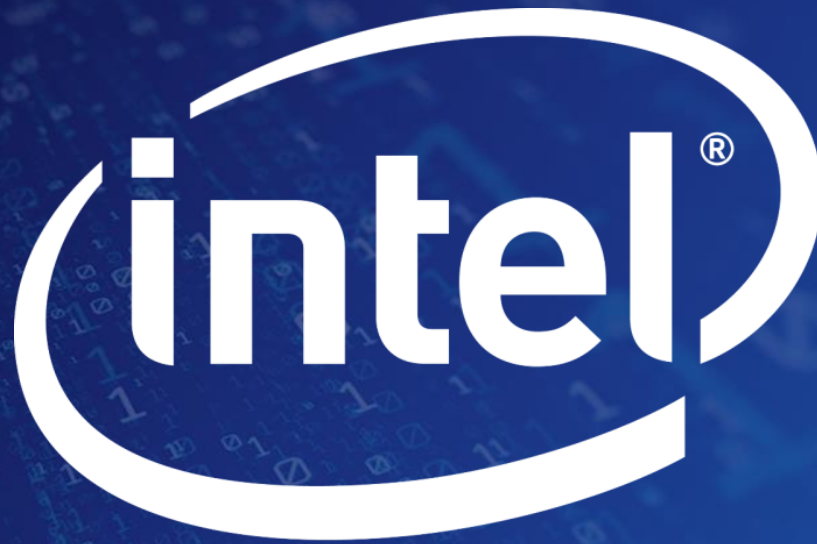


(4a)



(4a1)

Option 4 – NE DC



experience
what's inside™



NR Radio Frequency and co-existence

3GPP TSG RAN WG4 Chairman (Samsung)

Introduction | 3GPP RAN4 5G specifications



RF Requirements

- | RF specification for UE (**38.101-1/2/3**) and BS (**38.104**)
 - Operating bands and Channel arrangement
 - Transmitter RF requirements
 - Receiver RF requirements
- | EMC specification for UE (**38.124**) and BS (**38.113**)
 - EMC emission
 - EMC Immunity
- | MSR BS RF requirements (**37.104**)
 - RF requirements for Multi-Standard Radio BS

Baseband Requirements

- | Radio Resource Management (**38.133**)
 - Mobility
 - Timing
 - Measurement
- | UE (**38.101-4**) Demod/CSI and BS (**38.104**) Demod
 - PDSCH/PDCCH/SDR
 - PUSCH/PUCCH/PRACH
 - CSI/PMI/RI
 - CRI
 - Other PHY channel
 - Other channel state information

Test

- | BS conformance Test
 - Conducted Test (**38.141-1**)
 - Radiated Test (**38.141-2**)
- | NR test method (**38.810**)
 - RF testing method
 - RRM testing method
 - Demodulation Testing method

3GPP TS 38.101-1 V0.2.0 2017.10

3rd Generation Partnership Project;
Technical Specification Group Radio
Access Network;
NR;
User Equipment (UE) radio
transmission and reception Part 1:
Rang 1 standalone
(Release 15)

3GPP TS 38.104 V0.3.0 2017.10

3rd Generation Partnership Project;
Technical Specification Group Radio
Access Network;
NR;
Base Station (BS) radio
transmission and reception
(Release 15)








3GPP TS 38.133 V0.3.0 2017.10

3rd Generation Partnership Project;
Technical Specification Group Radio
Access Network;
NR;
Requirements for support of radio
resource management
(Release 15)

3GPP TS 38.141-1 V0.3.0 2017.10

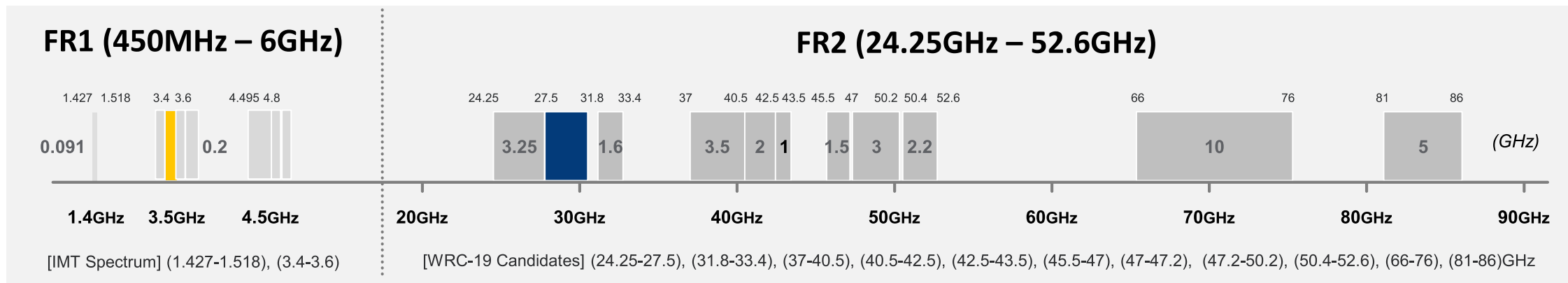
3rd Generation Partnership Project;
Technical Specification Group Radio Access
Network;
NR;
Base Station (BS) conformance testing;
Part1: Conducted conformance testing
(Release-15)

Content

-  NR System Parameters
 -  Spectrum/NR bands
 -  Channel Bandwidth
 -  Spectrum Utilization
 -  Guardband and Channel spacing
 -  Channel Raster
-  NR Radio Frequency Parameters

System Parameters | Spectrum

5G Candidate frequency bands for ITU-R WRC-19 (Nov. 2019)



New 5G frequency allocation status



USA

- 27.5 - 28.35GHz
- 37 - 38.6GHz
- 38.6 - 40GHz
- 37 – 43.5 GHz



Europe

- 3.4 – 3.8GHz
- 24.25 – 27.5GHz



China

- 3.3 – 3.6GHz
- 4.8 – 5.0GHz
- 24.25 – 27.5GHz
- 37 – 42.5GHz

Japan

- 3.6 - 4.2GHz
- 4.4 - 4.9GHz
- 27.5 - 29.5GHz



Korea

- 3.4 – 3.7GHz
- 26.5 – 29.5GHz

n77	3.3 – 4.2 GHz
n78	3.3 – 3.8 GHz
n79	4.4 – 5.0 GHz
n257	26.5 – 29.5 GHz
n258	24.25 – 27.5 GHz
n260	37 – 40 GHz
n261	27.5 – 28.35 GHz

System Parameters | NR Band Numbering

- Use prefix “n” to differentiate from E-UTRA bands and UTRA bands
- New bands for NR are assigned band numbers on a “first come first served” basis in reserved ranges regardless of duplex mode
- Reserved range is 65-256 for NR FR1 bands, 257-512 for NR FR2 bands

NR operating Band	Uplink (UL) operating band	Downlink (DL) operating band	Duplex Mode	
n1	1920MHz – 1980MHz	2110MHz-2170MHz	FDD] LTE Refarming Bands
:	:	:	:	
n77	3300MHz-4200MHz	3300MHz-4200MHz	TDD] NR FR1 new bands
:	:	:	:	
n257	26.5GHz – 29.5GHz	26.5GHz – 29.5GHz	TDD] NR FR2 new bands
:	:	:	:	
n512	:	:	:	

System Parameters | Channel Bandwidth



Fixed 15KHz SCS in LTE → Flexible SCS in NR

- 📶 Channel bandwidths depends on data subcarrier spacing (SCS) and frequency ranges
- 📶 Maximum Channel BW is specified assuming not over 3300 SC carriers and 4K FFT
- 📶 All channel bandwidth specified are mandatory except 90MHz in FR1 and 400MHz in FR2
- 📶 UE capability of supporting channel bandwidth is per band per SCS
- 📶 Separated capability for DL and UL. UE can operate with asymmetric UL and DL bandwidths
- 📶 New channel bandwidth can be added in the future release

NR band / SCS / UE Channel bandwidth													
LTE Refarming bands	SCS kHz	5 MHz	10 MHz	15 MHz	20 MHz	25 MHz	30 MHz	40 MHz	50 MHz	60 MHz	80 MHz	90MHz	100 MHz
n1	15	Yes	Yes	Yes	Yes								
	30		Yes	Yes	Yes								
	60		Yes	Yes	Yes								
n41	15		Yes	Yes	Yes			Yes	Yes				
	30		Yes	Yes	Yes			Yes	Yes	Yes	Yes	Yes	Yes
	60		Yes	Yes	Yes			Yes	Yes	Yes	Yes	Yes	Yes

NR band / SCS / UE Channel bandwidth													
NR Band in FR1	SCS kHz	5 MHz	10 MHz	15 MHz	20 MHz	25 MHz	30 MHz	40 MHz	50 MHz	60 MHz	80 MHz	90 MHz	100 MHz
n77	15		Yes	Yes	Yes			Yes	Yes				
	30		Yes	Yes	Yes			Yes	Yes	Yes	Yes	Yes	Yes
	60		Yes	Yes	Yes			Yes	Yes	Yes	Yes	Yes	Yes
n78	15		Yes	Yes	Yes			Yes	Yes				
	30		Yes	Yes	Yes			Yes	Yes	Yes	Yes	Yes	Yes
	60		Yes	Yes	Yes			Yes	Yes	Yes	Yes	Yes	Yes
n79	15							Yes	Yes				
	30							Yes	Yes	Yes	Yes	Yes	Yes
	60							Yes	Yes	Yes	Yes	Yes	Yes

Additional 30MHz and 70MHz Channel BW supported for N77,N78 in BS side ; 90MHz bandwidth supported in UE side is optional in Rel-15 for N77,N78 and N41

NR band / SCS / BS channel bandwidth					
NR Band in FR2	SCS kHz	50 MHz	100 MHz	200 MHz	400 MHz
n257	60	Yes	Yes	Yes	
	120	Yes	Yes	Yes	Yes
n258	60	Yes	Yes	Yes	
	120	Yes	Yes	Yes	Yes
n260	60	Yes	Yes	Yes	
	120	Yes	Yes	Yes	Yes
n261	60	Yes	Yes	Yes	
	120	Yes	Yes	Yes	Yes

System Parameters | Spectrum Utilization



- Spectrum Utilization (SU) is specified as Transmission Resource Block (RB) configuration in RAN4 specifications
- Spectrum utilization is specified as per combination of {CHBW, SCS}
- No specific waveform confinement technologies assumed (filtering, windowing, hybrid of them) for evaluating feasible SU
- Overall >90% SU achieved, maximum achieved SU are **98.3%** for FR1 and **95%** for FR2
- Spectrum Utilization is specified considering the forward compatibility
 - 📶 RAN4 defines a single set spectrum utilization (SU) values in Rel-15 for DL and UL
 - 📶 All the requirements defined in RAN4 based on Rel-15 SU
 - 📶 Meanwhile allow flexibility with higher values than RAN4 in RAN1/RAN2 protocol design

SCS (kHz)	5 MHz	10 MHz	15 MHz	20 MHz	25 MHz	30 MHz	40 MHz	50 MHz	60 MHz	70 MHz	80 MHz	90 MHz	100 MHz
	N _{RB}	N _{RB}	N _{RB}	N _{RB}	N _{RB}	N _{RB}	N _{RB}	N _{RB}	N _{RB}	N _{RB}	N _{RB}	N _{RB}	N _{RB}
15	25	52	79	106	133	160	216	270	N.A	N.A	N.A	N.A	N.A
30	11	24	38	51	65	78	106	133	162	189	217	245	273
60	N.A	11	18	24	31	38	51	65	79	93	107	121	135

SCS (kHz)	50 MHz	100 MHz	200 MHz	400 MHz
	NRB	NRB	NRB	NRB
60	66	132	264	N.A
120	32	66	132	264

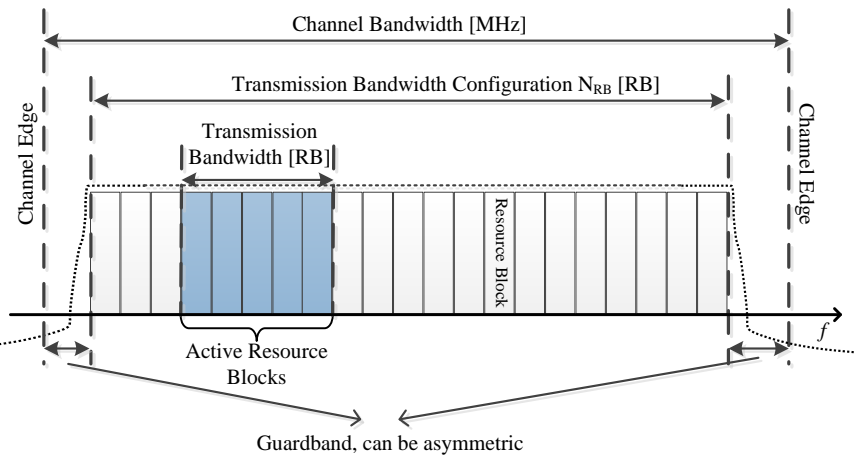
System Parameters | Guardband and Channel Spacing



A GLOBAL INITIATIVE

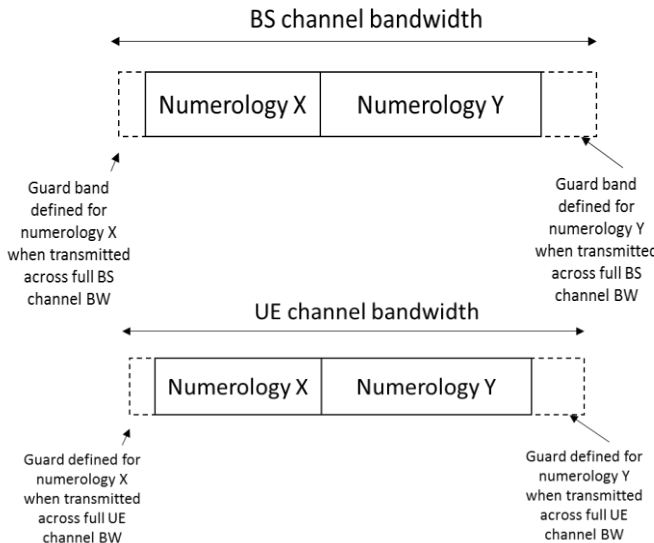
- Minimum guardband is specified based on channel bandwidth and transmission bandwidth configuration
- Minimum guardband for mixed numerologies is also specified
- Nominal Channel spacing for CA are also specified for different channel raster (100KHz, 15KHz, 60KHz)

Minimum Guardband

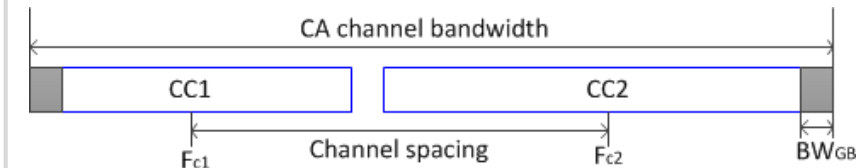


$$\text{Minimum guard-band} = (CHBW - SCS * 12 * NRB) / 2 - SCS / 2$$

GB for mixed numerologies



Channel Spacing



$$\text{Nominal channel spacing} = \left\lceil \frac{BW_{Channel(1)} + BW_{Channel(2)} - 2|GB_{Channel(1)} - GB_{Channel(2)}|}{0.6} \right\rceil 0.3 \text{ [MHz]}$$

$$\text{Nominal channel spacing} = \left\lceil \frac{BW_{Channel(1)} + BW_{Channel(2)} - 2|GB_{Channel(1)} - GB_{Channel(2)}|}{0.015 * 2^{\alpha}} \right\rceil 0.015 * 2^{\alpha} \text{ [MHz]}$$

$$\text{Nominal channel spacing} = \left\lceil \frac{BW_{Channel(1)} + BW_{Channel(2)} - 2|GB_{Channel(1)} - GB_{Channel(2)}|}{0.06 * 2^{\alpha}} \right\rceil 0.06 * 2^{\alpha} \text{ [MHz]}$$

System Parameters | Channel Raster



- The channel raster defines RF reference frequencies to identify channel position for both DL and UL
- A global frequency raster is defined between 0 -100GHz as NR-ARFCN
- The granularity of the global frequency raster is ΔF_{Global} :
 - 📶 For FR1 below 3GHz: 5kHz
 - 📶 For FR1 above 3GHz: 15kHz
 - 📶 For FR2: 60kHz
- The RF channel positions on the channel raster in each NR operating band are given through the applicable NR-ARFCN
- Band specific raster granularity ΔF_{Raster} , which may be equal to or larger than ΔF_{Global} :
 - 📶 FR1: LTE reframing bands except band 41, 100kHz aligned with LTE
 - 📶 FR1: New frequency ranges above 3GHz and band 41: SC based 15kHz, 30kHz
 - 📶 FR2: SC based 60kHz, 120kHz
- Similar global raster and band specific raster concept is also used to define Sync Raster

Content

-  NR System Parameters

-  NR RF Parameters

 -  Transmitter Power

 -  Unwanted Emission

 -  REFSENS

 -  ACS

Transmitter Power | UE FR1(38.101-1)



Power class (PC)

- Power class 3: 23dBm
- Power class 2: 26dBm
- Power class 3 is default power class



Maximum Power Reduction (MPR)

- UE is allowed to reduce the maximum output power due to higher order modulations and transmit bandwidth configurations
- For certain waveform and modulation scheme combination, MPR is defined according to RB allocation range, i.e., outer RB allocation and inner RB allocation



Additional Maximum Power Reduction (A-MPR)

- Additional maximum power reduction (A-MPR) is allowed to meet additional emission requirements which can be signalled by the network (NS value)



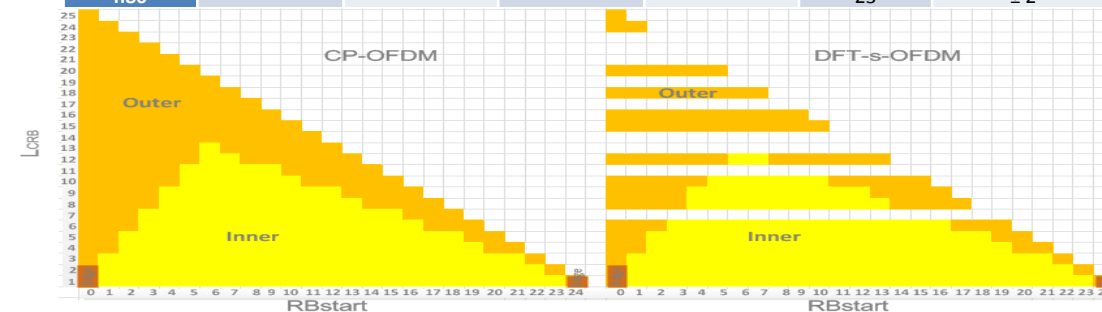
Configured transmitted power (Pcmax)

- The UE is allowed to set its configured maximum output power within the bounds, i.e., range of Pcmax



MPR, A-MPR and Pcmax are also specified for CA, DC, SUL and UL-MIMO

NR band	Class 1 (dBm)	Tolerance (dB)	Class 2 (dBm)	Tolerance (dB)	Class 3 (dBm)	Tolerance (dB)
n1					23	± 2
n2					23	$\pm 2^3$
n3					23	$\pm 2^3$
n5					23	± 2
n7					23	$\pm 2^3$
n8					23	$\pm 2^3$
n12					23	$\pm 2^3$
n20					23	$\pm 2^3$
n25					23	± 2
n28					23	+2 / - 2.5
n34					23	± 2
n38					23	± 2
n39					23	± 2
n40					23	± 2
n41			26	+2/-3 ³	23	$\pm 2^3$
n50					23	± 2
n51					23	± 2
n66					23	± 2
n70					23	± 2
n71					23	+2 / - 2.5
n74					23	± 2
n77			26	+2/-3	23	+2/-3
n78			26	+2/-3	23	+2/-3
n79			26	+2/-3	23	+2/-3
n80					23	± 2
n81					23	± 2
n82					23	± 2
n83					23	$\pm 2/-2.5$
n84					23	± 2
n86					23	± 2



Transmitter Power | FR2 UE and EN-DC (38.101-2 and 38.101-3)



- Power class definition package for FR2 UE
 - Minimum peak EIRP-> UL coverage for network link budget
 - Maximum TRP-> UL interference restriction
 - Maximum EIRP-> Regulatory requirement
 - EIRP at certain % of CDF-> Spatial coverage
- MPR, A-MPR and P_{cm} are specified for each power class for FR2 UE
- MPR, A-MPR and P_{cm} are also specified for CA and UL-MIMO
- Transmitter power including Power class, MPR, A-MPR and P_{cm} are also defined for EN-DC UE

PC#	Min Peak EIRP (dBm)		Spherical coverage		Max. EIRP (dBm)		Max. TRP (dBm)		UE type
	28GHz	39GHz	28GHz	39GHz	28GHz	39GHz	28GHz	39GHz	
1	40.0	38.0	32.0dBm@85%	30.0dBm@85%	55	55	35	35	Fixed Wireless Access (FWA) on fixed platform
2	29.0	N/A	18.0dBm@60%	N/A	43	N/A	23	N/A	Vehicle mounted UE (fixed on moving platform)
3	22.4	20.6	11.5dBm@50%	8.0dBm@50%	43	43	23	23	Handheld UE
4	34.0	31.0	25.0dBm@20%	19.0dBm@20%	43	43	23	23	Higher power mobile UE

Note: The spherical coverage requirements in this table are only applicable for UE which supports single band in FR2

Output Power | BS

- Output power is specified per BS class (Wide area, Medium Range, Local area) and per BS type (BS 1-C, BS 1-H and BS 1-O)
- No upper limit is defined for Wide Area BS output power
- $10\log(N_{\text{TXU,counted}})$ is used to derive rated carrier output power from output power per TAB connector for BS 1-H
- No upper limits for output power is specified for BS type 2-O in Rel-15

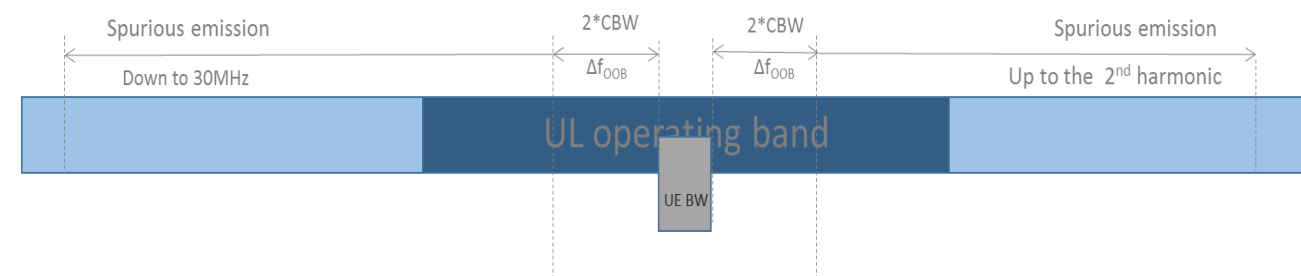
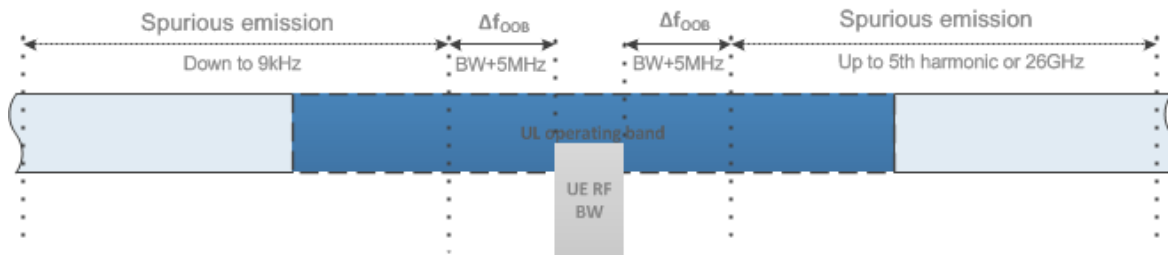
	BS 1-C	BS 1-H		BS 1-O
	The rated carrier output power per antenna connector	The sum of rated carrier output power for all TAB connectors for a single carrier	The rated carrier output power per TAB connector	Rated carrier TRP output power declared per RIB
Wide Area BS	No upper limit for Wide Area Base Station			
Medium Range BS	$\leq 38 \text{ dBm}$	$\leq 38 \text{ dBm} + 10\log(N_{\text{TXU,counted}})$	$\leq 38 \text{ dBm}$	$\leq + 47 \text{ dBm}$
Local Area BS	$\leq 24 \text{ dBm}$	$\leq 24 \text{ dBm} + 10\log(N_{\text{TXU,counted}})$	$\leq 24 \text{ dBm}$	$\leq + 33 \text{ dBm}$

Unwanted emission | UE output RF spectrum emission



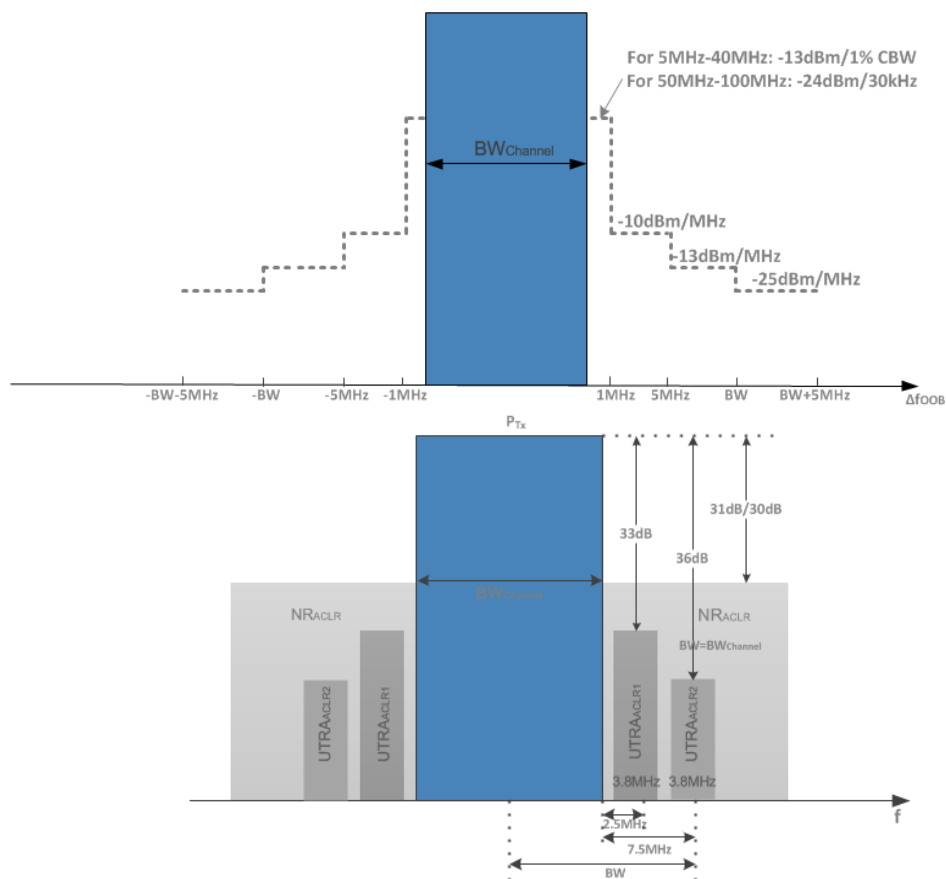
UE output RF spectrum emission consists of

- 📶 **Out-of-band (OOB) emission:** unwanted emissions immediately outside the assigned channel bandwidth resulting from the modulation process and non-linearity in the transmitter. OOB emission is specified in terms of
 - 📶 **Spectrum Emission Mask (SEM)**
 - Starting from each edge of the assigned NR channel bandwidth to $\pm(BW_{\text{channel}} + 5\text{MHz})$ for FR1
 - Starting from each edge of the assigned NR channel bandwidth to $\pm 2 * BW_{\text{channel}}$ for FR2
 - 📶 **Adjacent Channel Leakage Ratio (ACLR)**
 - NR ACLR and UTRA ACLR for FR1
 - NR ACLR for FR2
- 📶 **Spurious emission:** caused by unwanted transmitter effects such as harmonics emission, parasitic emissions, intermodulation products and frequency conversion products
 - 📶 Frequency range up to 5th harmonic or 26GHz for FR1
 - 📶 Frequency range up to 2nd harmonic range of UL operating band for FR2



Unwanted emission | UE OOB emission

FR1 OOB Emission



FR2 OOB Emission

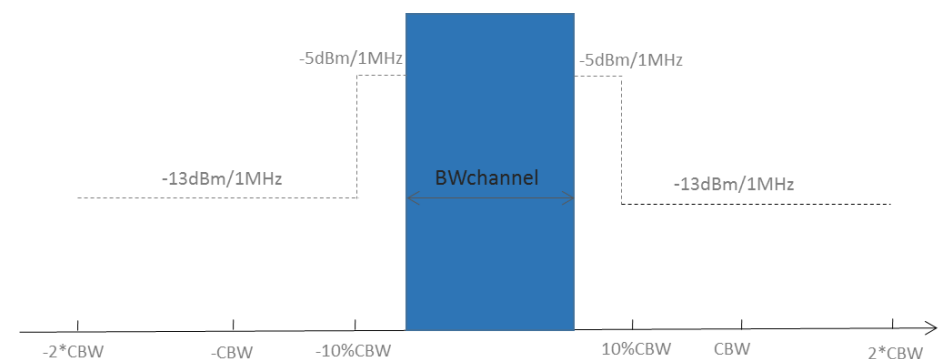


Figure 1: General NR spectrum emission mask

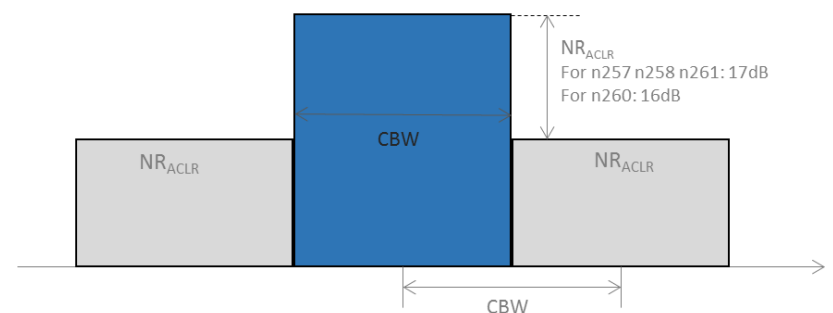


Figure 1: NR_{ACLR} requirement

Unwanted emission | BS unwanted emissions



Basic limit and scaling

- Basic limit is applied for each antenna connector as emission requirements for BS 1-C
- Emission requirements are scaled by $10\log_{10}(N_{TXU, \text{counted per cell}})$ for 1-H and 9dB for 1-O except co-location requirements
- No scaling is applied for FR2



BS unwanted emission consists of

Out-of-band (OOB) emission:

Operating band unwanted emissions (OBUE)

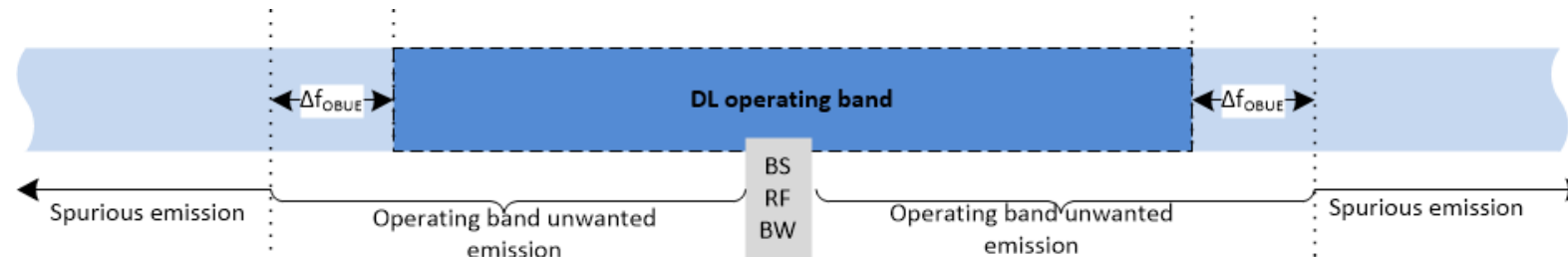
- OBUE is specified as band centric manner with offset Δf_{OBUE}
- Both Category A and Category B limits are specified for FR1

Adjacent Channel Leakage Ratio (ACLR)

- NR ACLR1/ACLR2 are specified for FR1. LTE ACLR1/ACLR2 are specified for FR1 band also operating as E-UTRA or UTRA
- Only NR ACLR1 is specified for FR2
- Absolute ACLR limit or relative ACLR is applied, which is less stringent.

Spurious emission

- From 9 kHz to 12.75GHz (up to 5th harmonic limit of the downlink operating band for certain bands) for FR1 (excluding OBUE region)
- From 30MHz to 2nd harmonic of the upper frequency edge of the DL operating band for FR2 (excluding OBUE region)
- Both Category A and Category B limits are specified for NR BS spurious emission for FR1



For FR1, REFSENS power level is defined as

$$\text{Sensitivity} = -174\text{dBm}(kT) + 10 \cdot \log(R_x BW) + NF + SNR + IM - \text{diversity gain}$$

Where RAN4 assume

- SNR = -1dB, IM (Implementation Margin) = 2.5dB, Diversity Gain = 3dB for 2Rx
- Noise Figure: 9dB for LTE refarming band; 10dB for n77 (3.3GHz – 3.8GHz), n78, n79; 10.5dB for n77 (3.8GHz- 4.2GHz)

For FR1, both 2Rx REFSENS (for all bands) and 4Rx REFSENS (for n7, n38, n41, n77, n78, n79) are defined.

For FR2, REFSENS power level is the EIS level in the RX beam peak direction.

For CA and EN-DC, additional relaxation are defined for below cases.

- Band combination specific Δ RIB for FR1 inter-band CA
- Aggregated Channel BW specific Δ RIB for FR2 intra-band continuous CA, i.e., 0.5dB for aggregated CHBW >800MHz
- Band combination specific MSD for the band impacted by harmonic interference and intermodulation interference for CA and EN-DC.

For BS 1-C and BS 1-H, REFSENS power level is defined as

$$\text{Sensitivity} = -174\text{dBm}(kT) + 10 \cdot \log(R_x BW) + NF + SNR + IM$$

Where RAN4 assume

- SNR = BW specific value, IM (Implementation Margin) = 2dB
- Noise Figure: 5 dB for Wide Area BS, 10 dB for Medium Range BS and 13 dB for Local Area BS

For BS type 1-O, OTA Reference sensitivity level is a directional requirement specified as an EIS level over declared OTA REFSENS RoAoA.

For BS type 2-O, a range of OTA reference sensitivity is defined for vendor to declare specific value for each BS class.

- The declared reference sensitivity value is per polarization
- 2dB antenna gain difference between 28GHz and 39GHz assumed to maintain the UL same coverage

BS channel bandwidth [MHz]	Subcarrier spacing [kHz]	FRC for REFSENS as example
5, 10, 15	15	G-FR1-A1-1
10, 15	30	G- FR1-A1-2
10, 15	60	G- FR1-A1-3
20, 25, 30, 40, 50	15	G- FR1-A1-4
20, 25, 30, 40, 50, 60, 70, 80, 90, 100	30	G- FR1-A1-5
20, 25, 30, 40, 50, 60, 70, 80, 90, 100	60	G- FR1-A1-6

BS class	G	
	30 GHz (24.25 – 33.4 GHz)	45GHz (37 – 52.6 GHz)
WA	10 to 33 dBi	12 to 35 dBi
MR	5 to 28 dBi	7 to 30 dBi
LA	0 to 23 dBi	2 to 25 dBi

Frequency range	30 GHz (24.25 – 33.4 GHz)	45GHz (37 – 52.6 GHz)
BS	10 dB	12 dB

- For FR1, different ACS minimum requirement are specified for bands below 2.7GHz and bands above 3.3GHz
 - 📶 For bands below 2.7GHz, ACS is scaled for channel BW larger than 10MHz to keep the same 33dB ACS as LTE
 - 📶 For bands above 3.3GHz, 33dB ACS is specified for all channel bandwidth
- For FR2, the ACS requirement is verified with the test metric of EIS.
 - 📶 28GHz band: 23dB ACS
 - 📶 39GHz band: 22 dB ACS
- It is not possible to directly measure ACS, instead the lower and upper range of test parameters are chosen to verify ACS



- For BS 1-C and BS 1-H, same conductive ACS requirements as LTE is specified for all NR BS classes
- For BS 1-O, ACS is applied when AoA of wanted signal and interference signal are within the minSENS RoAoA.
- For BS 2-O ACS is applied when AoA of wanted signal and interference signal are within FR2 OTA REFSENS RoAoA. Requirements are derived based on co-existence study
 - 📶 24dBc for 24.24 – 33.4 GHz frequency range.
 - 📶 23dBc for 37 – 52.6 GHz frequency range.

For more Information:



info@3gpp.org



www.3gpp.org

Search for WIDs at <http://www.3gpp.org/specifications/work-plan> and http://www.3gpp.org/ftp/Information/WORK_PLAN/ (See excel sheet)

RWS-180012

Workshop on 3GPP Submission Towards IMT-2020

24-25 October 2018

Brussels, Belgium

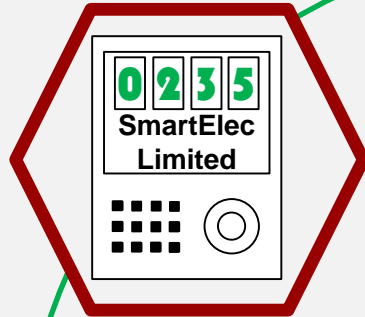


3GPP's Low-Power Wide-Area IoT Solutions: NB-IoT and eMTC

Low-power wide-area IoT

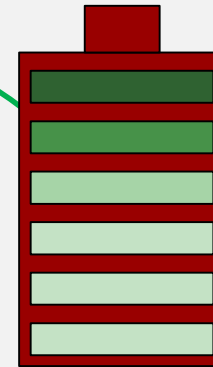
Connection density

1 000 000
UEs/km²



UE battery life

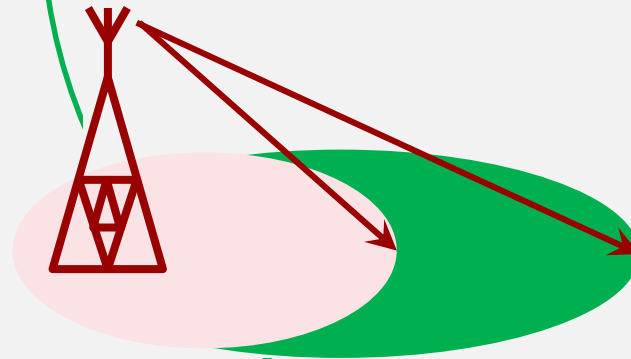
10 – 15 years in
164 dB MCL



Four KPIs for 3GPP LPWA IoT solutions

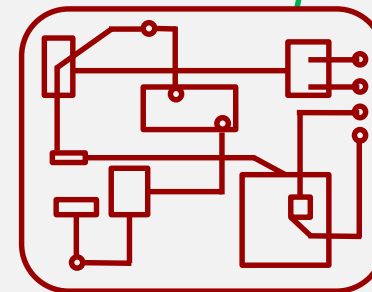
Coverage extension

164 dB MCL
@160 bps

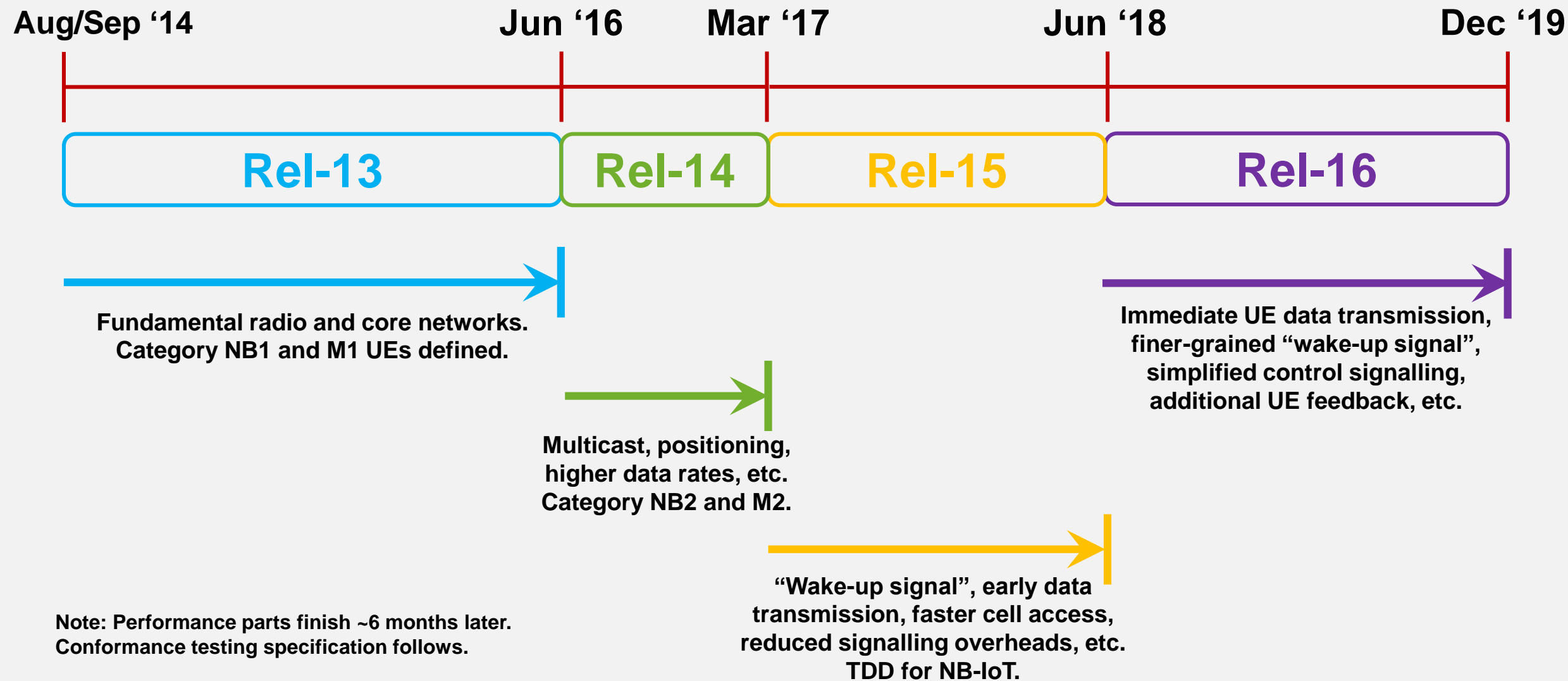


UE complexity and cost

Ultra-low

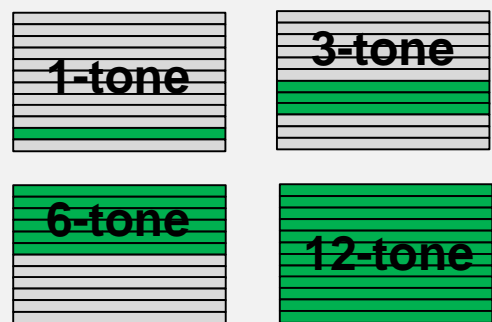


NB-IoT and eMTC project timelines

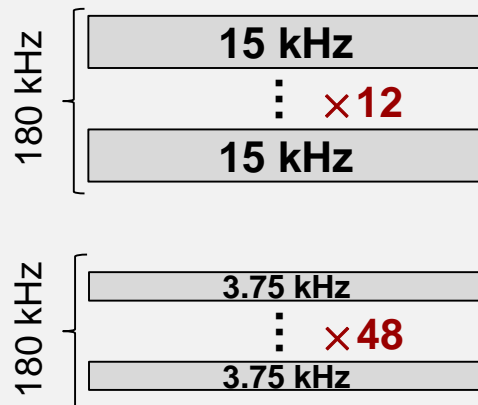


mMTC connection density

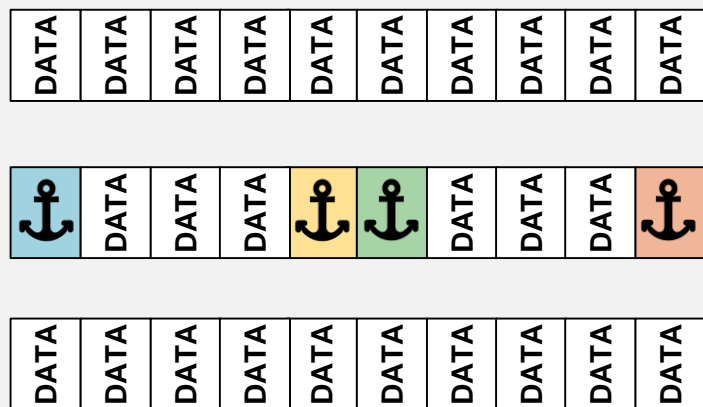
NB-IoT



Single-tone and 3/6/12-tone
UL allocations

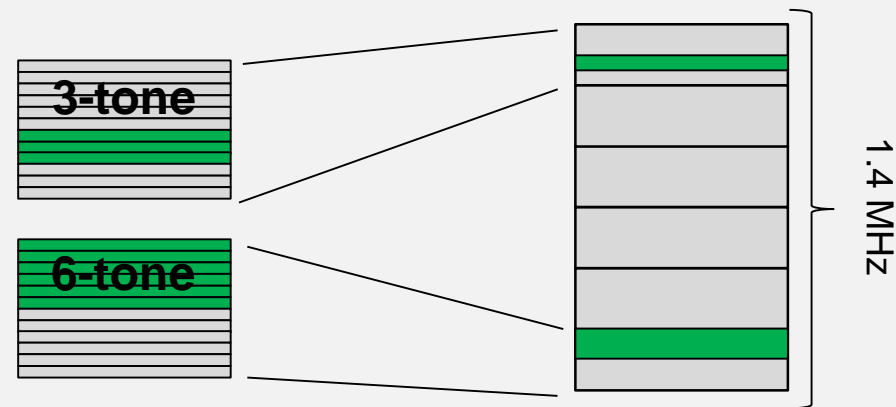


Dense subcarrier spacing

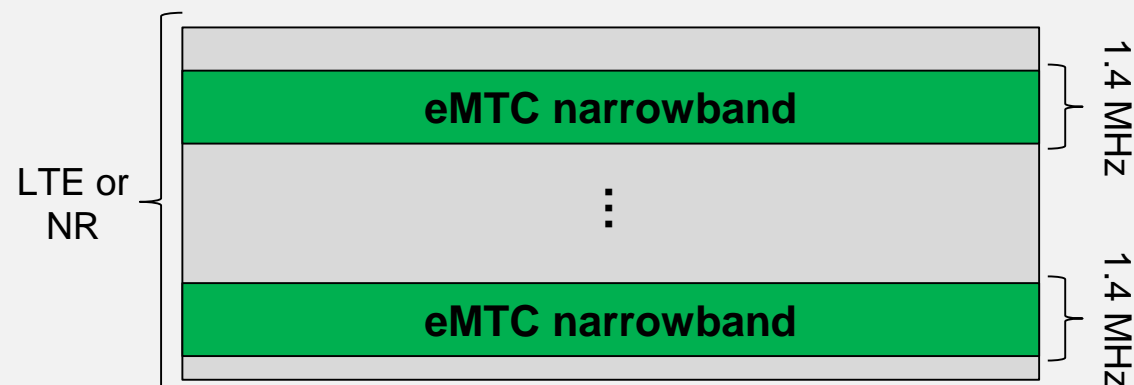


Non-anchor carriers
for capacity and
load-balancing

eMTC



3- and 6-tone allocations within a PRB
of a 1.4 MHz narrowband



Deploy multiple independent eMTC
narrowbands within LTE/NR bandwidth

Ultra-low UE complexity: Signal processing simplifications

1 ms

0	1	0	1	0	1	1	1	0	0	1	0	1	0	1	0
1	1	0	0	1	0	0	1	1	0	0	1	0	0	1	0
0	1	1	0	1	0	0	1	1	0	1	1	1	1	0	0
1	1	0	1	0	1	0	1	0	0	0	1	0	0	0	1
0	1	0	1	1	0	1	1	0	0	1	1	0	0	1	0
0	1	1	1	0	1	0	1	1	0	0	1	0	1	0	1
0	1	1	1	0	1	0	0	1	0	1	0	1	0	1	0
1	1	1	0	1	1	1	1	1	0	1	1	0	1	1	0
1	0	1	0	0	1	0	0	0	1	0	0	1	0	0	1

Cat. 1 data

10 000 bits / ms

1 ms

1	0	1	1	1	0	1	1
0	0	0	1	0	0	1	0
1	0	0	0	1	0	0	0
0	1	1	1	0	1	1	0
0	1	1	0	0	1	0	1
1	1	0	1	1	1	1	0
1	0	1	0	1	0	0	1

Cat. M1 data

1000 bits / ms

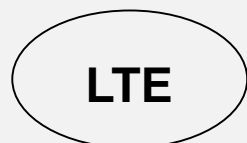
Up to 10 ms

1	0	1	1	1	1	0
1	1	0	0	0	1	0
0	1	0	1	0	0	0
1	0	0	1	0	1	1
1	0	1	0	0	0	1
1	0	0	1	0	1	1
1	0	1	0	0	1	1

Cat. NB1 data

UL: 1000 bits / up to 10 ms

DL: 680 bits / up to 10 ms

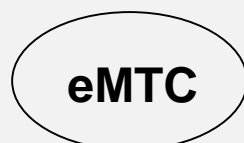


1 ms

?	?	?	?	?	?	?	?
?	?	?	?	?	?	?	?
?	?	?	?	?	?	?	?
?	?	?	?	?	?	?	?
?	?	?	?	?	?	?	?
?	?	?	?	?	?	?	?

Control channel

~40 candidates / ms

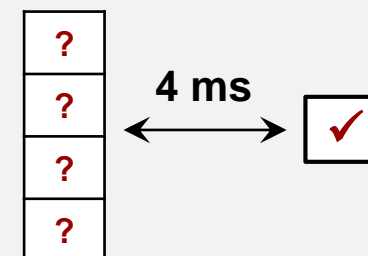
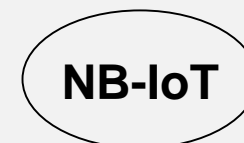


1 ms

?	?	?	?
?	?	?	?
?	?	?	?
?	?	?	?

Control channel

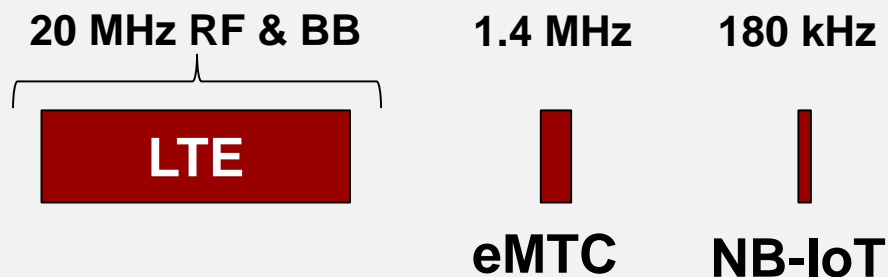
~16 candidates / ms



Control channel

~1 candidate / ms

Ultra-low UE complexity: Hardware simplifications

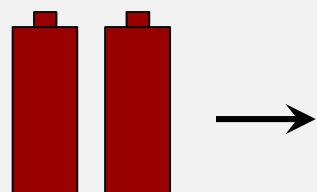


RF bandwidth \Rightarrow RF hardware cost

BB bandwidth \Rightarrow signal processing cost

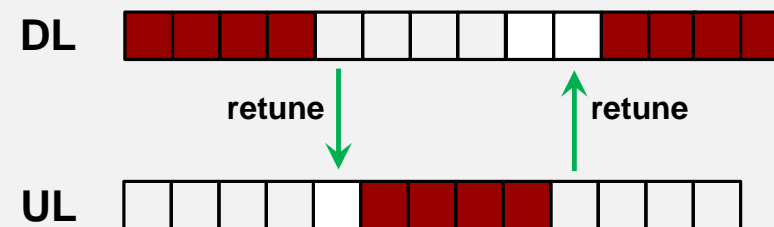


Single receive RF chain for UE



20 dBm and 14 dBm UE transmit power classes

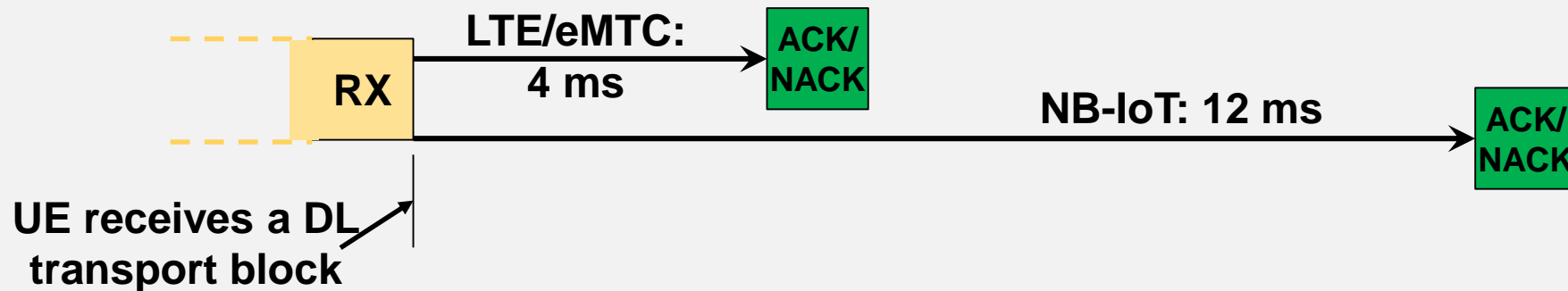
Lower peak current requirement allows cheaper, smaller batteries



Half-duplex operation allows removal of duplexer from UE
(Mandatory NB-IoT, optional eMTC)

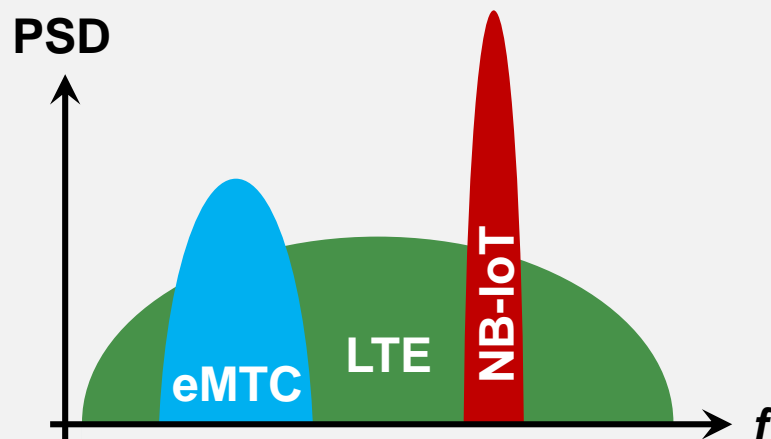
Ultra-low UE complexity: Further steps in NB-IoT

- NB-IoT takes additional steps to allow low-cost hardware:
 - Downlink uses convolutional encoding, removing need for turbo decoder in UE
 - 1 or 2 HARQ processes, instead of 8 in LTE/eMTC, reduces memory for data buffering
 - Synchronization signals with low complexity, optimised for reception in deep coverage
 - Maximum modulation is QPSK instead of 16-QAM, lessening EVM requirements
 - UE is allowed a much longer time to decode a reception before reacting to it, e.g. for DL:

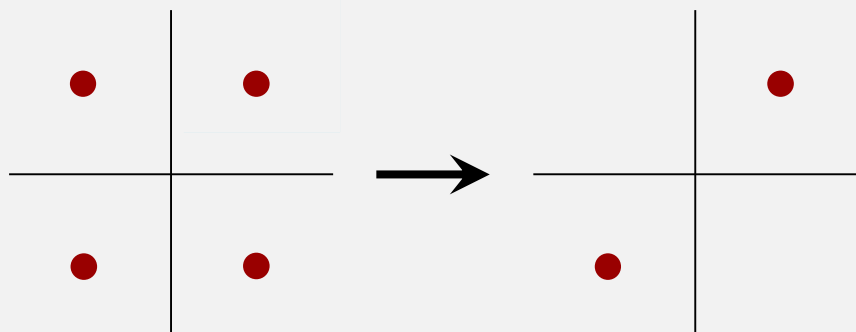


- 40 ms gap after each 256 ms of transmission during UL, allowing UE to re-sync to DL
 - Allows lower-cost non-temperature compensated crystal oscillators to be used in chipsets
 - Mandatory in NB-IoT UEs, optional for eMTC

Coverage extension

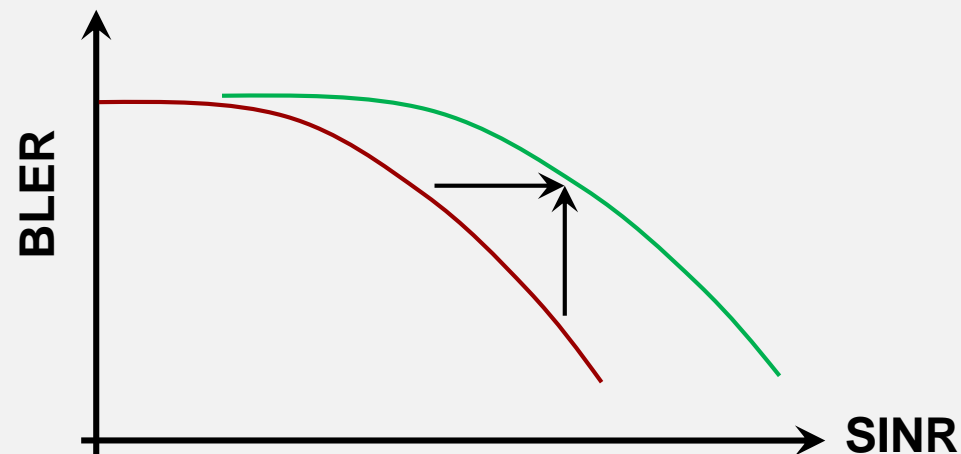
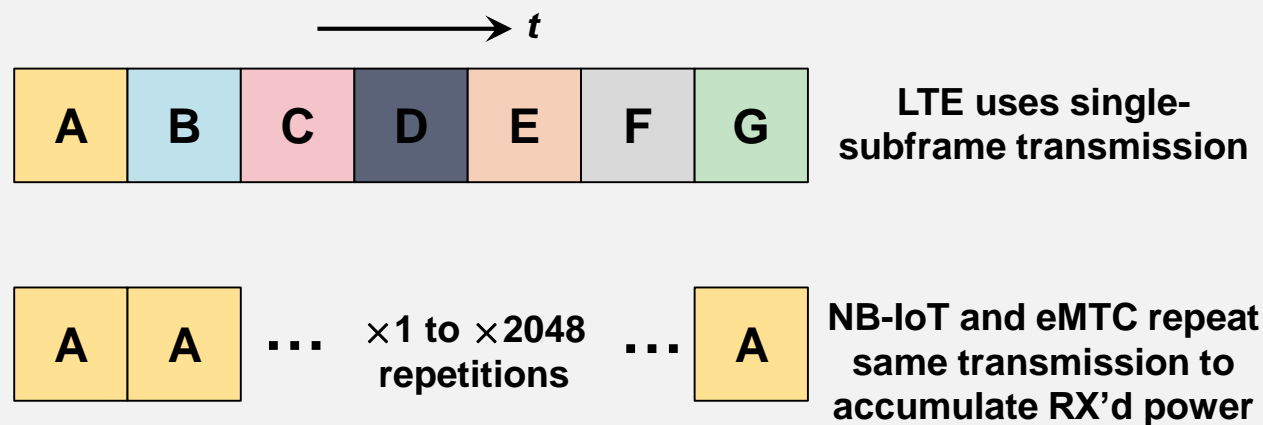


PSD boost in bandwidth as small as 3.75 kHz



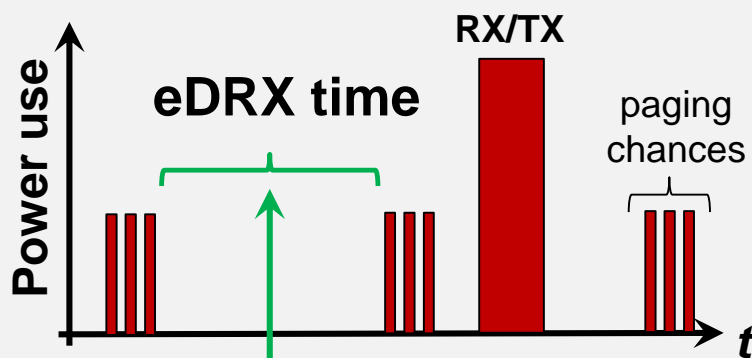
Low-PAPR $\pi/2$ -BPSK modulation
(and $\pi/4$ -QPSK in NB-IoT)

HUAWEI TECHNOLOGIES CO., LTD., Proprietary

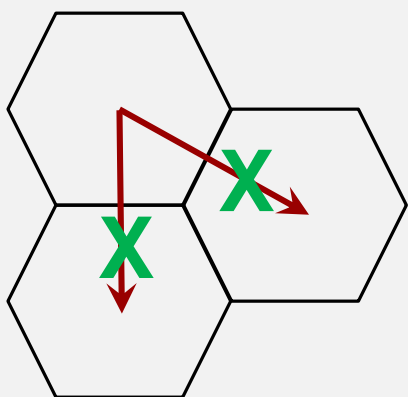
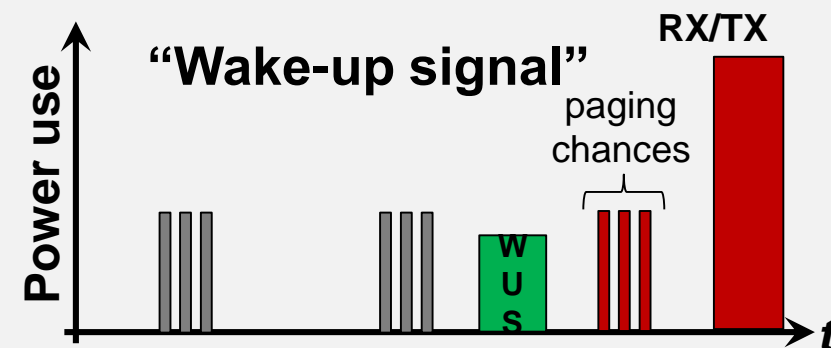
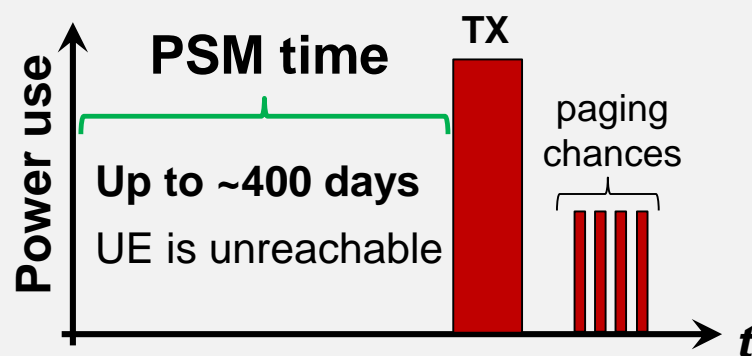


Relaxed requirements to tolerate lower SINR regimes

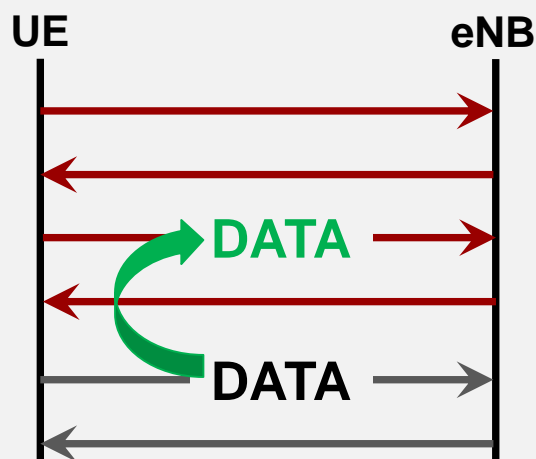
Battery life 10 – 15 years



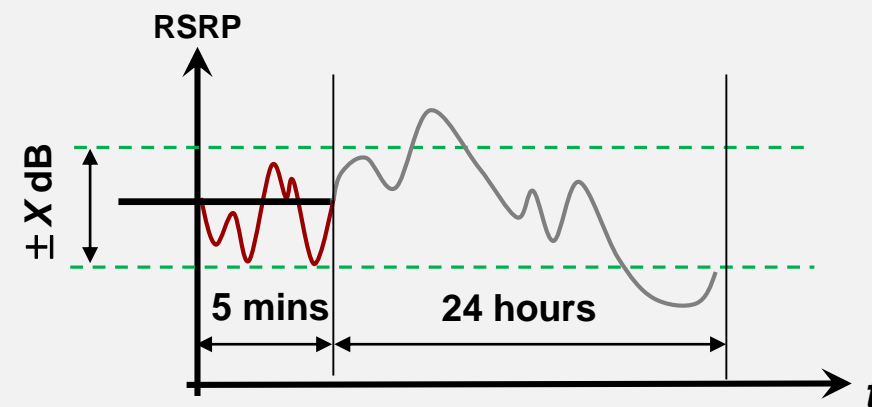
NB-IoT: ≤ 3 hr
eMTC: ≤ 40 min



NB-IoT: No handover
measurements / signalling



Earlier data transmission, without
tx/rx'ing to complete connection

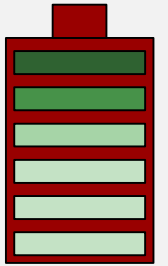


Stationary UE can suspend
measurements of neighbour cells

Hallmarks of 3GPP LPWA IoT technologies

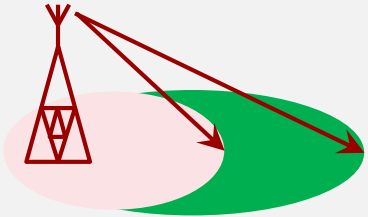
Battery life of 15 years or more on 2AA cells (5 Wh)

- Optimised for small infrequent packet transmissions e.g. 50-200 bytes few times/day
 - Transfer data earlier with fewer transmissions, and less battery consumption
- Maximise time UE can spend in low-power states and eliminate avoidable UE RX/TX



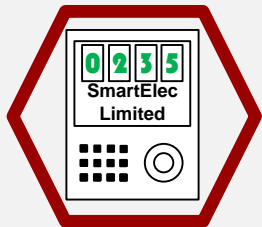
Support for normal to moderate coverage and deep coverage scenarios

- Repetition, PSD boosting, and low-PAPR transmissions
- In good coverage, NB-IoT and eMTC do not need repetitions



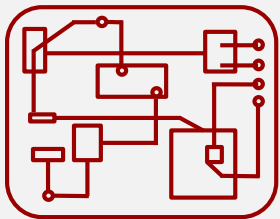
mMTC connection density of $\geq 1\,000\,000$ UE/km²

- Small resource allocations, 3.75 kHz subcarriers (NB-IoT), scalable network capacity
- Reduced signalling overhead to free-up resources for connecting more devices per cell



Complexity and cost is much lower than MBB devices

- Reduced RF and baseband bandwidths of 1.4 MHz for eMTC and 180 kHz for NB-IoT
- Relaxed signal processing requirements, with further relaxations in NB-IoT



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THANK YOU

www.huawei.com

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LTE evolution

Asbjörn Grövlén
Ericsson

Overview



- 📶 LTE is submitted as part of the SRIT to IMT-2020
- 📶 What has happened in LTE since the IMT-Advanced submission?
 - 📶 Lots!

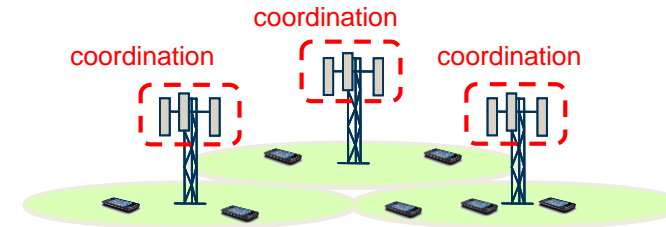


Coordinated Multi-Point Operation

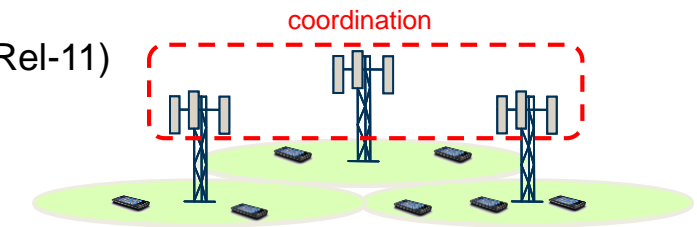
Introduced coordination across antenna points

Reducing inter-cell interference, improving coverage

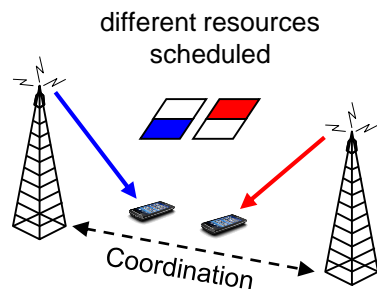
Many coordination schemes require fast backhaul



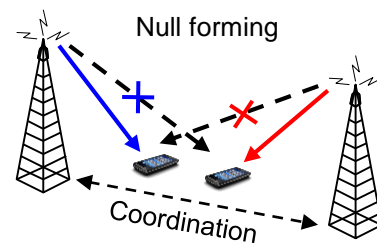
Intra-site coordination only (Rel-11)



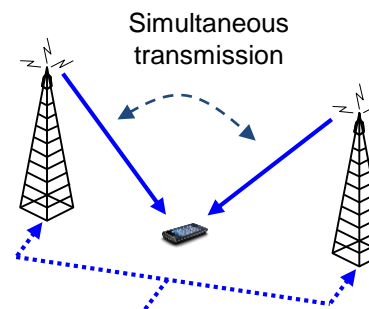
Inter-site coordination (Rel-12)



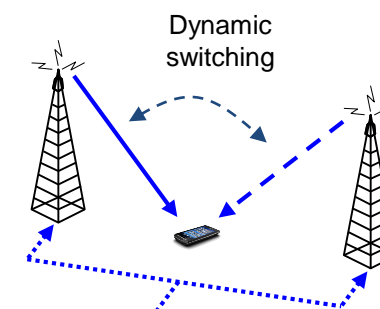
Dynamic Point Blanking



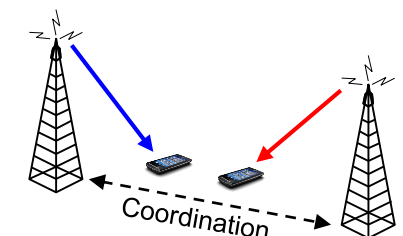
Coordinated Beamforming



Joint transmission



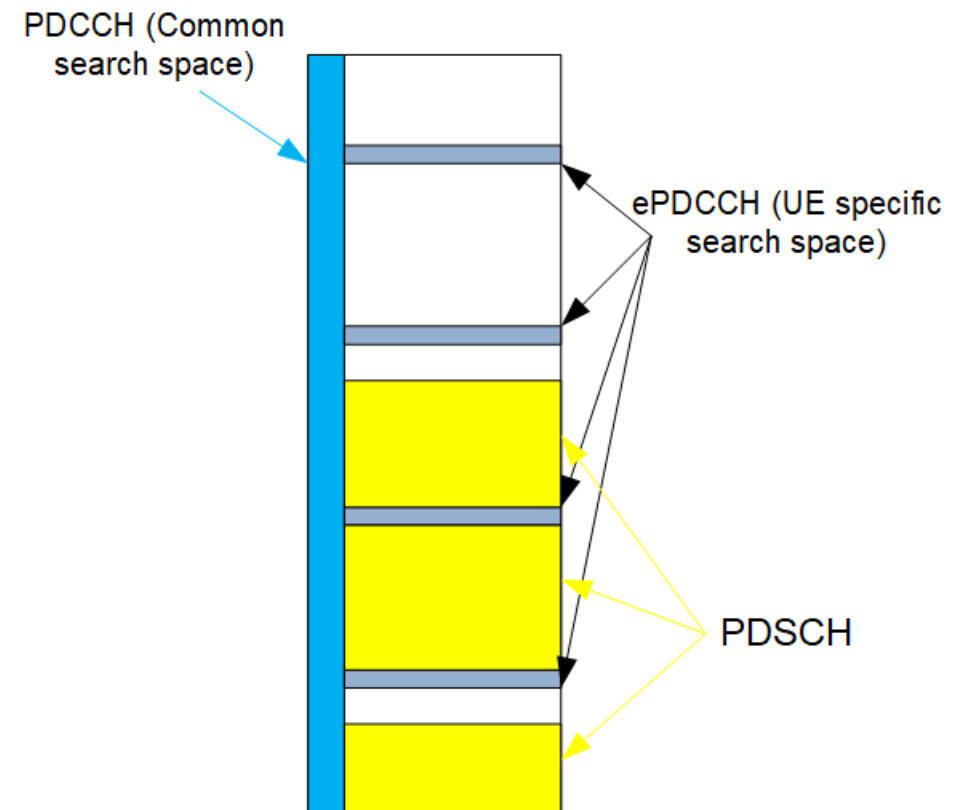
Dynamic Point Selection



Coordinated Link Adaptation

Enhanced downlink control channel

- PDCCH is
 - 📶 always full bandwidth
 - 📶 using common reference signal (CRS)
- EPDCCH introduced to support
 - 📶 increased control channel capacity
 - 📶 frequency-domain ICIC
 - 📶 improved spatial reuse of control channel resource
 - 📶 beamforming and/or diversity
- The EPDCCH can
 - 📶 be transmitted multiplexed with PDSCH
 - 📶 coexist with legacy UEs on the same carrier
- DMRS are used for demodulation



Dual connectivity

Control and user plane separation

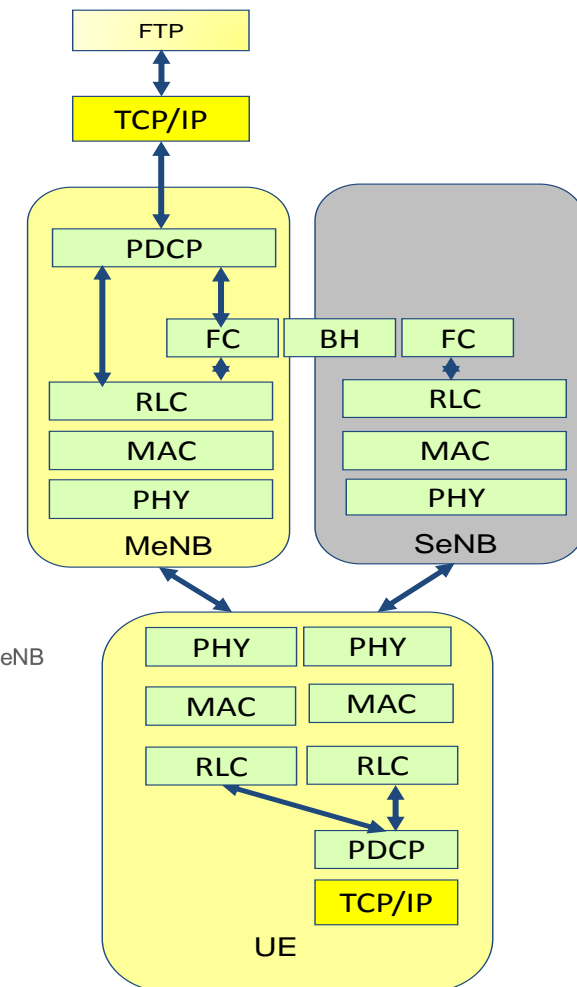
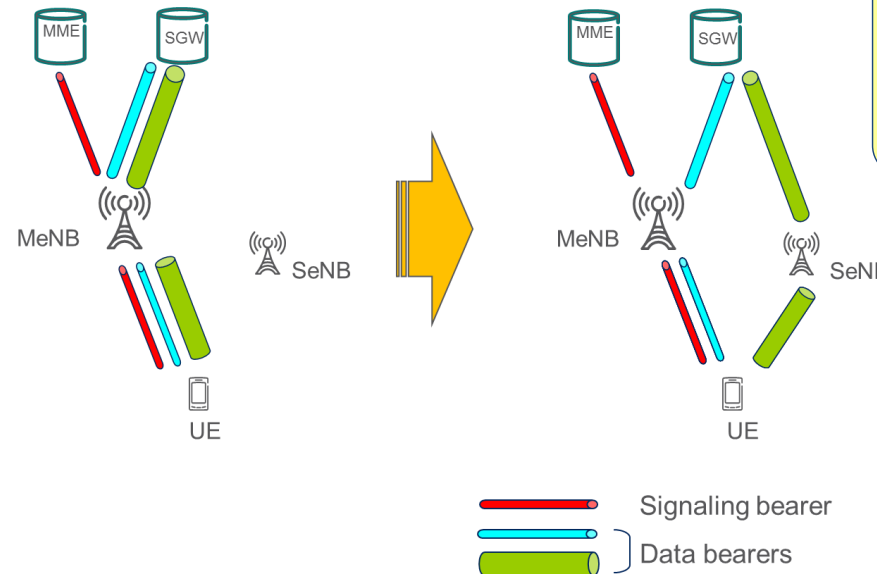
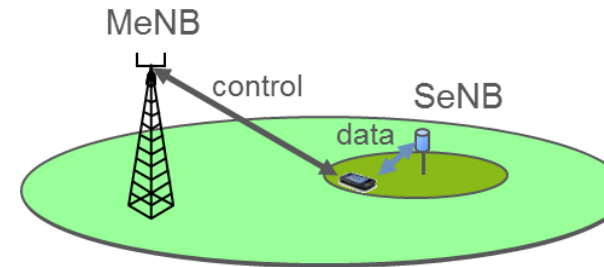
- DL (Rel-12)
- UL (Rel-13)

Benefits

- Increased mobility robustness
- Minimize UE context transfer
- Minimize re-establishment failures

Split bearer

- Data is split on the PDCP layer
- Transparent to higher layer protocols
- Service specific offloading



Small cells

Rel-11→



Dynamic TDD (eIMTA)



Certain subframes within the radio frame can be dynamically switch between UL and DL



256QAM



1024 QAM also supported in DL



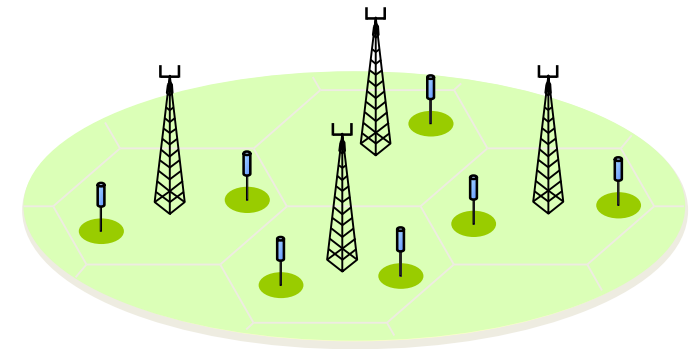
Allow small cells to be turned on/off with low latency



Discovery signal



Radio interface based inter-cell synchronization



Proximity services (ProSe) and vehicle-to-everything (V2X)

Rel-12→



➤ The introduction of the sidelink interface enables direct UE-to-UE communications

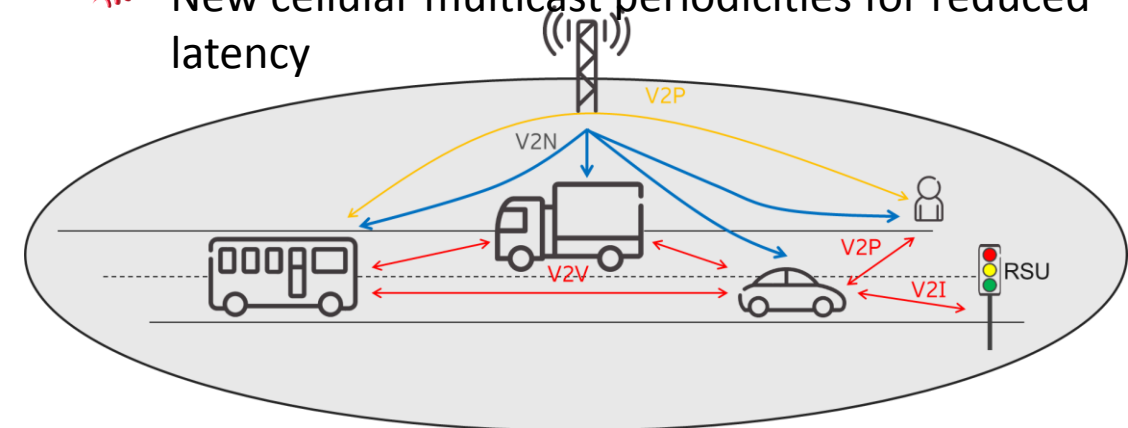
➤ The cellular interface was enhanced to handle efficiently unicast and broadcast traffic

➤ Use cases

- Mission critical push-to-talk for first responders (ProSe, Rels. 12-13)
- Discovery (ProSe, Rels. 12-13)
- Vehicular day-1 safety services such as CAM and DENM (V2X, Rel. 14)
- Truck platooning, advanced driving, vehicle sensor sharing (V2X, Rel. 15)

➤ Features

- UE-autonomous resource allocation and NW-managed resource allocation for sidelink
- Distributed synchronization for operation outside network coverage
- New physical layer format for high mobility scenarios (V2X)
- Aggregation of multiple sidelink carriers
- New cellular multicast periodicities for reduced latency



Licensed-Assisted Access

Rel-13 Licensed assisted access

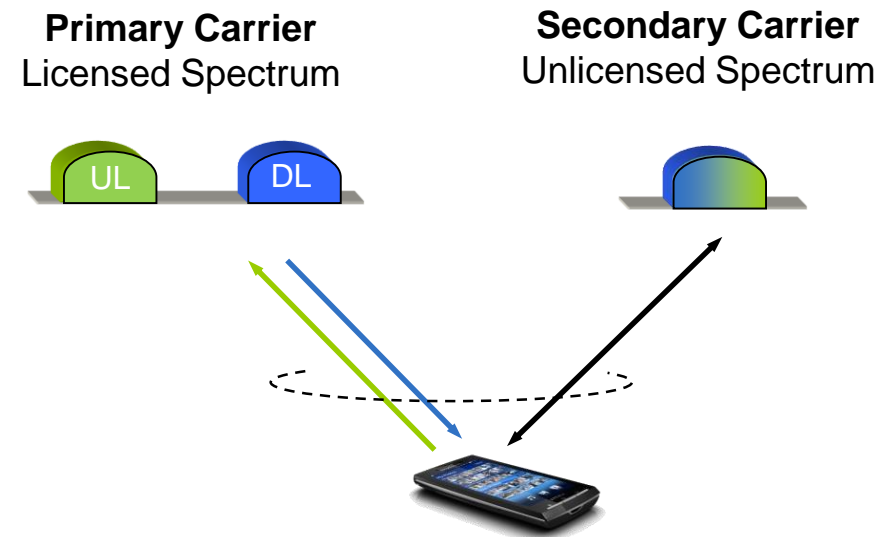
- Enable gigabit throughput LTE via carrier aggregation framework
- Downlink only access to 5 GHz unlicensed bands

Rel-14 Enhanced LAA

- Introduce scheduled uplink access to unlicensed bands

Rel-15 Further enhanced LAA

- Enhance uplink access throughput and latency with configured grants (aka “autonomous UL”)

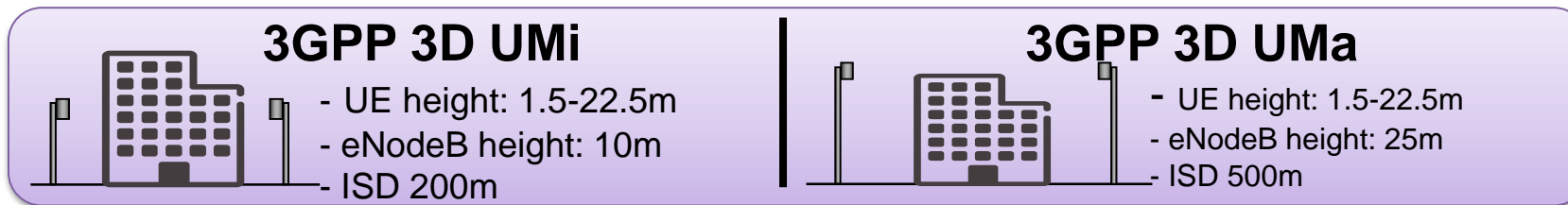
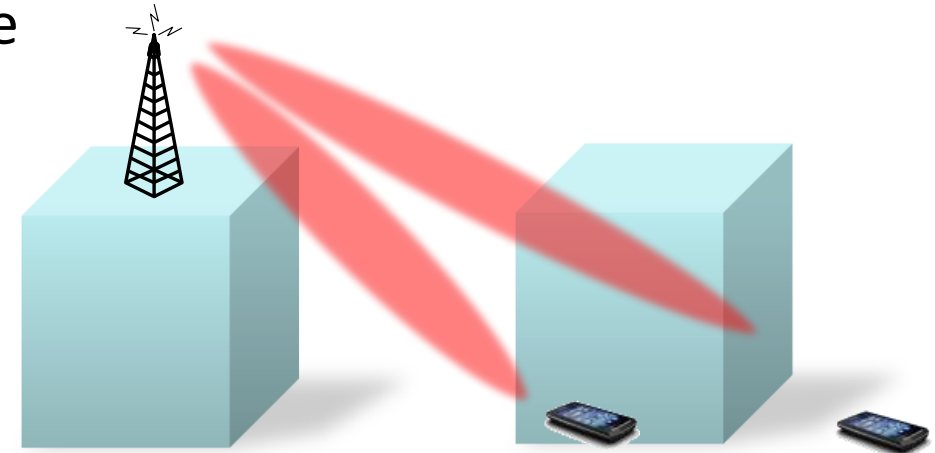


Elevation Beamforming/ Full-Dimension MIMO

Rel-13→

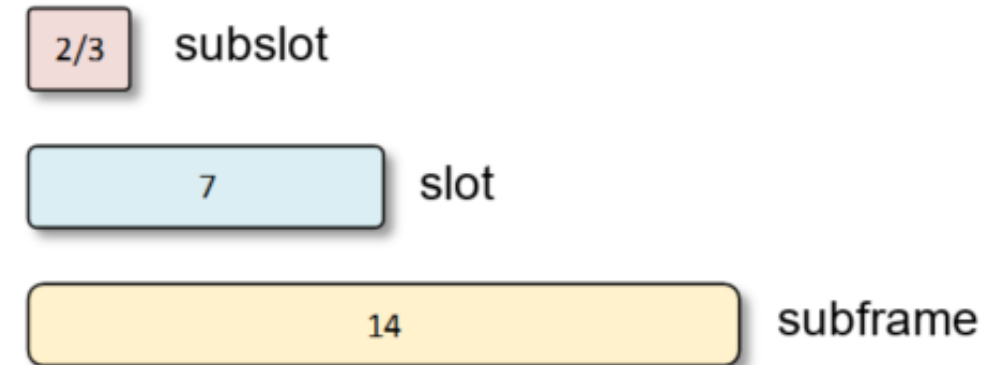


- With the introduction of advance antenna systems with more antenna elements, exploiting all three dimensions for MIMO becomes possible
- A 3D channel model was developed
- Feature components
 - Increased number CSI-RS ports to 12 and 16
 - Beam selection
 - SRS enhancements for low delay spread channels
 - DMRS enhancements to increase the number of co-scheduled UEs



Shortened TTI and processing time

- Shortened TTI and processing time for LTE introduces the possibility for subslot- (2 or 3 symbols long) and slot-based transmission, each associated with a short processing time.
- A shortened processing time of $n+3$ (compared to $n+4$) has also been introduced for subframe-based transmissions
- DL and UL control channels have been redesigned (SPDCCH and SPUCCH for UL and DL respectively) ensuring backwards compatibility with existing LTE operation
- Higher layer improvements to latency have also been introduced



Summary



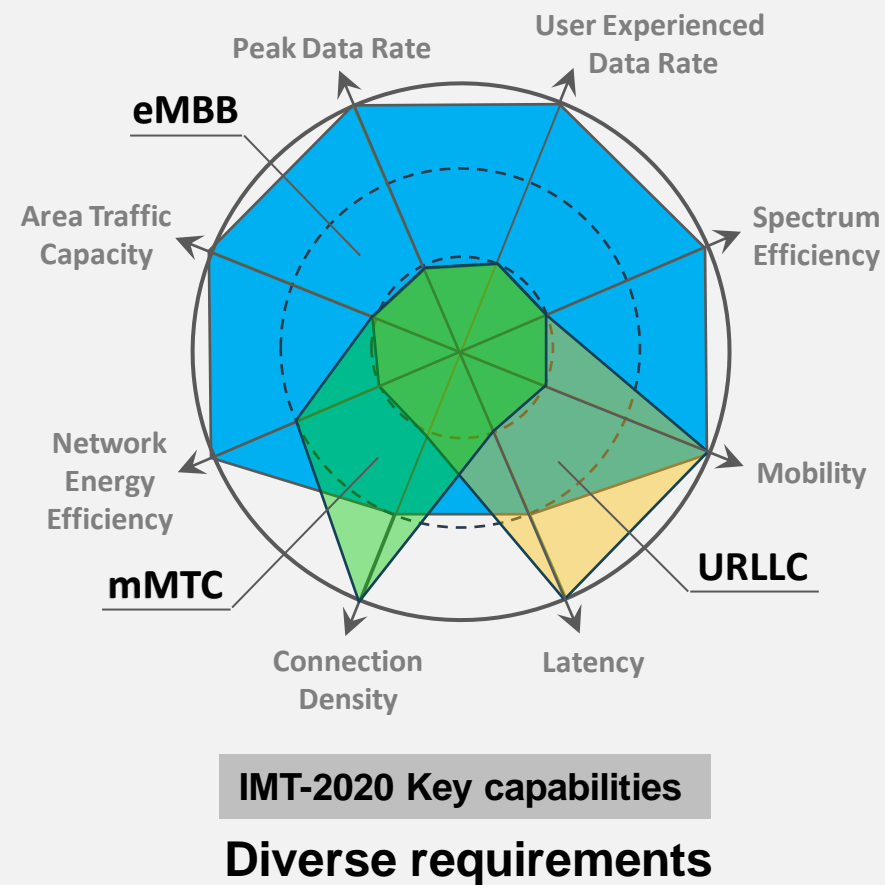
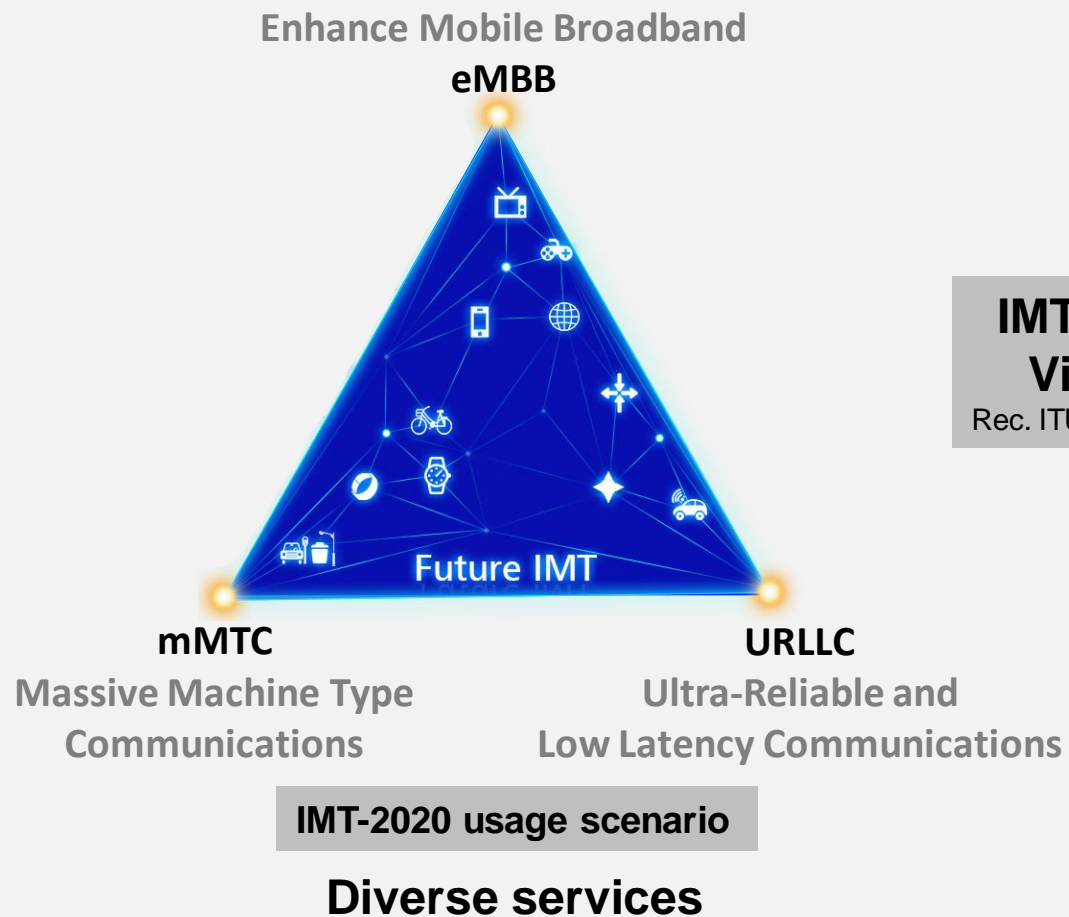
- Continuous enhancements have improved LTE meeting the IMT-2020 requirements of a component RIT

Overview of 3GPP Submission *and* Compliance to IMT-2020 Requirements

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

WU Yong
wuyong@huawei.com

3GPP 5G meets IMT-2020 vision



3GPP “5G” aims to meet IMT-2020 vision capabilities

Overview of 3GPP submission

Name : **5G**

Footnote: Developed by 3GPP as 5G, Release 15 and beyond

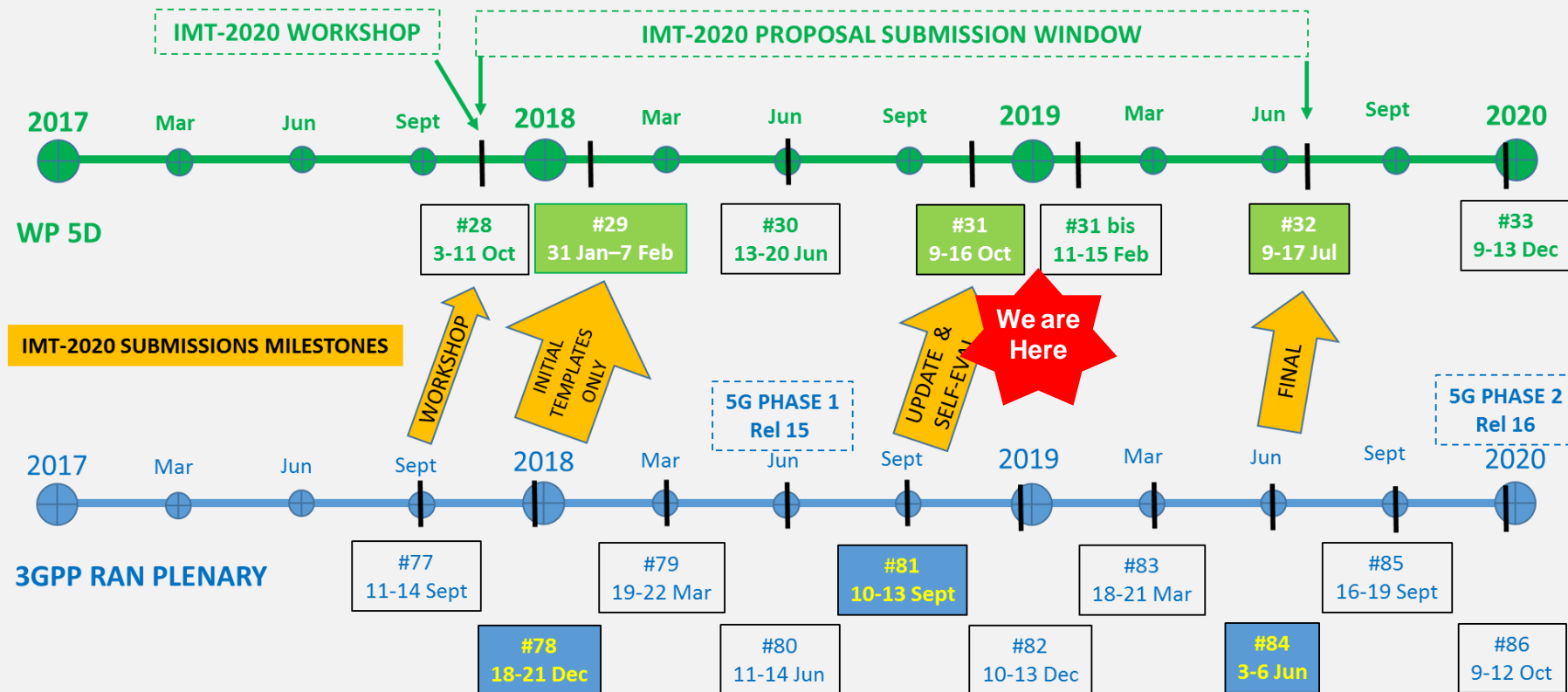


Submission 1: SRIT

- Component RIT: **NR**
- Component RIT: **EUTRA / LTE**
- Include LTE-NR Dual connectivity (DC)



Submission 2: NR RIT



3GPP provided updated submission with preliminary self evaluation to WP 5D in LAST WEEK

3GPP submission templates

According to Report ITU-R M.2411 “Requirements, Evaluation criteria, and submission templates for the development of IMT-2020”.

3GPP provided the following submission templates and preliminary self evaluation

Description templates

Characteristics templates (RP-182052)

- For SRIT (NR+LTE)
- For NR RIT



Link budget template (RP-182110)

- NR in 4 test environments,
- LTE in 2 test environments

Compliance templates

Compliance templates (RP-182053)

- For SRIT (NR+LTE)
- For NR RIT

On

- ✓ Service, Spectrum and Technical performance requirement

Self evaluation report TR37.910v1.0.0

- Based on evaluation guidelines defined in Report ITU-R M.2412.
- **Preliminary results for Rel-15**
 - ✓ **NR RIT**: 5 test environments for eMBB, URLLC and mMTC
 - ✓ **LTE RIT**: Rural – eMBB and Urban Macro – mMTC
 - ✓ May be further updated before final submission



IMT-2020 submission

3GPP Submission Templates Description templates - Characteristics



Characteristics template for SRIT of “5G” (Release 15 and beyond)

The description templates provided by 3GPP are for the description of the characteristics of 5G¹ developed by 3GPP. It includes one characteristics template for SRIT (encompassing NR and LTE), and one characteristics template for NR RIT.

This document provides the characteristics template for the description of the characteristics of the SRIT which consists of two component RITs “NR” and “LTE”, based on 3GPP Rel-15 work.

It is noted that new features in addition to the ones provided in this characteristics template might be included in future update for the SRIT and its component RITs.

For this characteristics template, 3GPP has addressed most of the characteristics that are viewed to be helpful to assist in evaluation activities for independent evaluation groups, as well as to facilitate the understanding of the state-of-art of 3GPP development on the SRIT. In future submission, further information will be included.

Characteristics template for NR RIT of “5G” (Release 15 and beyond)

The description templates provided by 3GPP are for the description of the characteristics of 5G¹ developed by 3GPP. It includes one characteristics template for SRIT (encompassing NR and LTE), and one characteristics template for NR RIT.

This document provides the characteristics template for the description of the characteristics of the NR RIT based on 3GPP Rel-15 work.

It is noted that new features in addition to the ones provided in this characteristics template might be included in future update for the RIT.

For this characteristics template, 3GPP has addressed most of the characteristics that are viewed to be helpful to assist in evaluation activities for independent evaluation groups, as well as to facilitate the understanding of the state-of-art of 3GPP development on the RIT. In future submission, further information will be included.

Item	Item to be described
5.2.3.2.1	Test environment(s)
5.2.3.2.1.1	What test environments (described in Report ITU-R M.2412-0) does this technology description template address? <i>This proposal targets to addresses all the five test environments across the three usage scenarios (eMBB, mMTC, and URLLC) as described in Report ITU-R M.2412-0.</i>

- 3GPP provided characteristics description for SRIT (NR+LTE) and NR RIT for most items.
- The description on new and key functionalities are the basis for ITU evaluation.

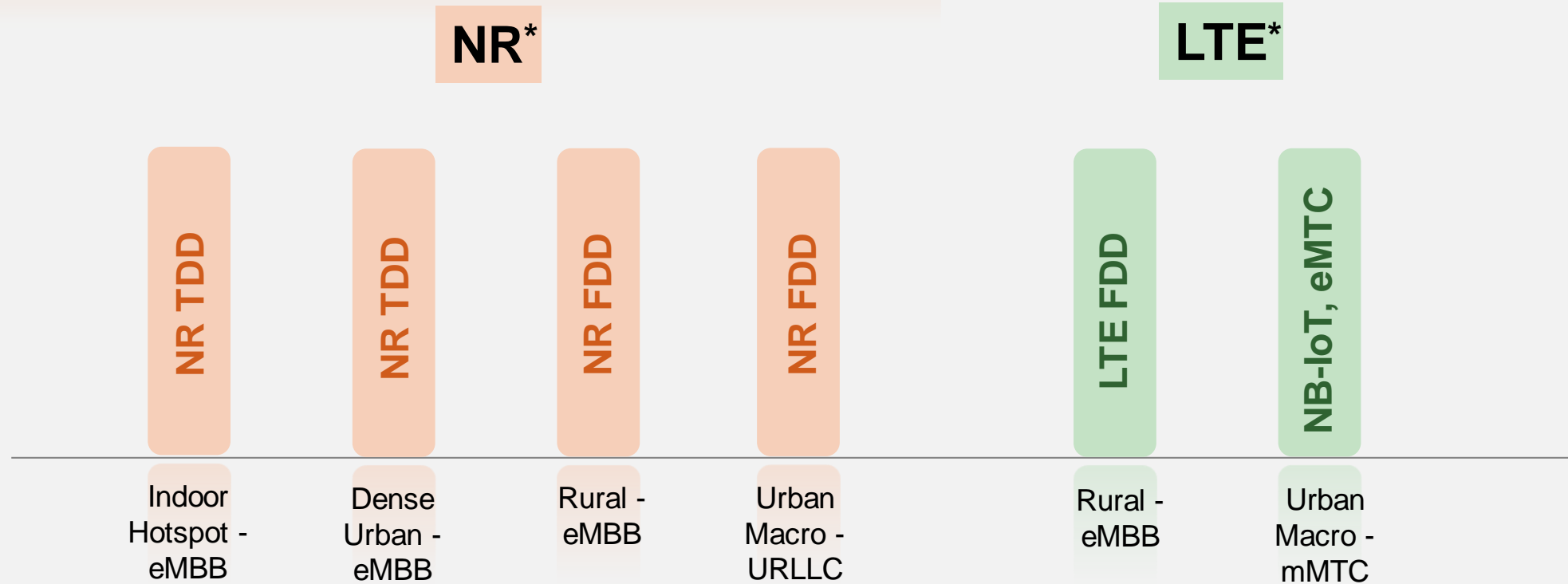
- Test environment(s)
- Radio interface functional aspects (multiple access, modulation, PAPR, coding scheme)
- Channel tracking capabilities (e.g., pilot symbol configuration)
- Physical channel structure and multiplexing
- Mobility management (Handover)
- Radio resource management
- Frame structure
- Spectrum capabilities and duplex technologies
- Support of Advanced antenna capabilities
- Link adaptation and power control
- Power classes
- Scheduler, QoS support and management, data services
- Radio interface architecture and protocol stack
- Cell selection
- Location determination mechanisms
- Priority access mechanisms
- Unicast, multicast and broadcast
- Privacy, authorization, encryption, authentication and legal intercept schemes
- Frequency planning
- Interference mitigation within radio interface
- Synchronization requirements
- Support for wide range of services
- Global circulation of terminals
- Energy efficiency
- Other items

3GPP Submission Templates

Description templates – Link budget



- 3GPP provided initial link budget for NR and LTE, respectively.
- The coverage capability of 3GPP 5G is verified.



* For both channel model A and B

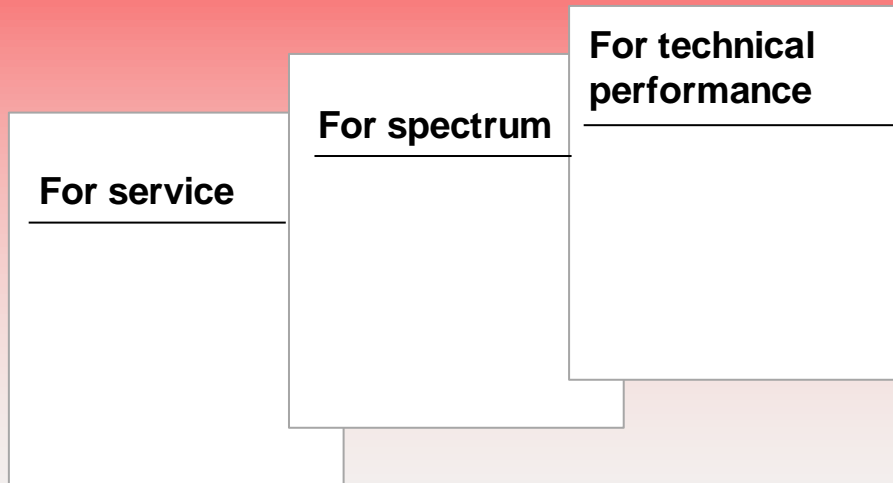
3GPP Submission Templates

Compliance templates



Compliance templates

- To assess the compliance of the proposal with the minimum requirements



- 3GPP provided initial compliance template for
 - **SRIT** (NR+LTE)
 - **NR RIT**
 - Based on the preliminary self evaluation results.
- The compliance assessment is applied to IMT-2020 requirements as defined in Report ITU-R M.2411, including
 - Service requirement
 - Spectrum requirement
 - Technical performance requirements.
- It is shown that both SRIT and NR RIT are fully compliant with IMT-2020 requirements.

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)

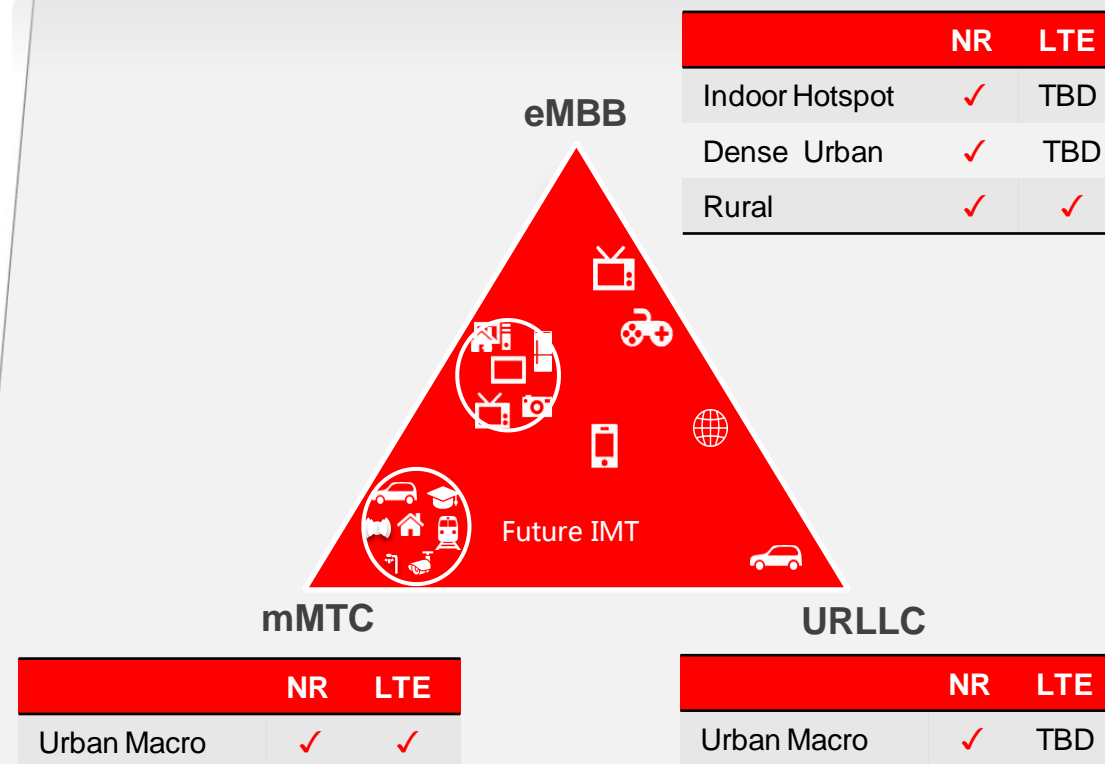
5G

3GPP
A GLOBAL INITIATIVE

A GLOBAL INITIATIVE

3GPP
A GLOBAL INITIATIVE

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



3GPP Compliance to Service and Spectrum Requirement



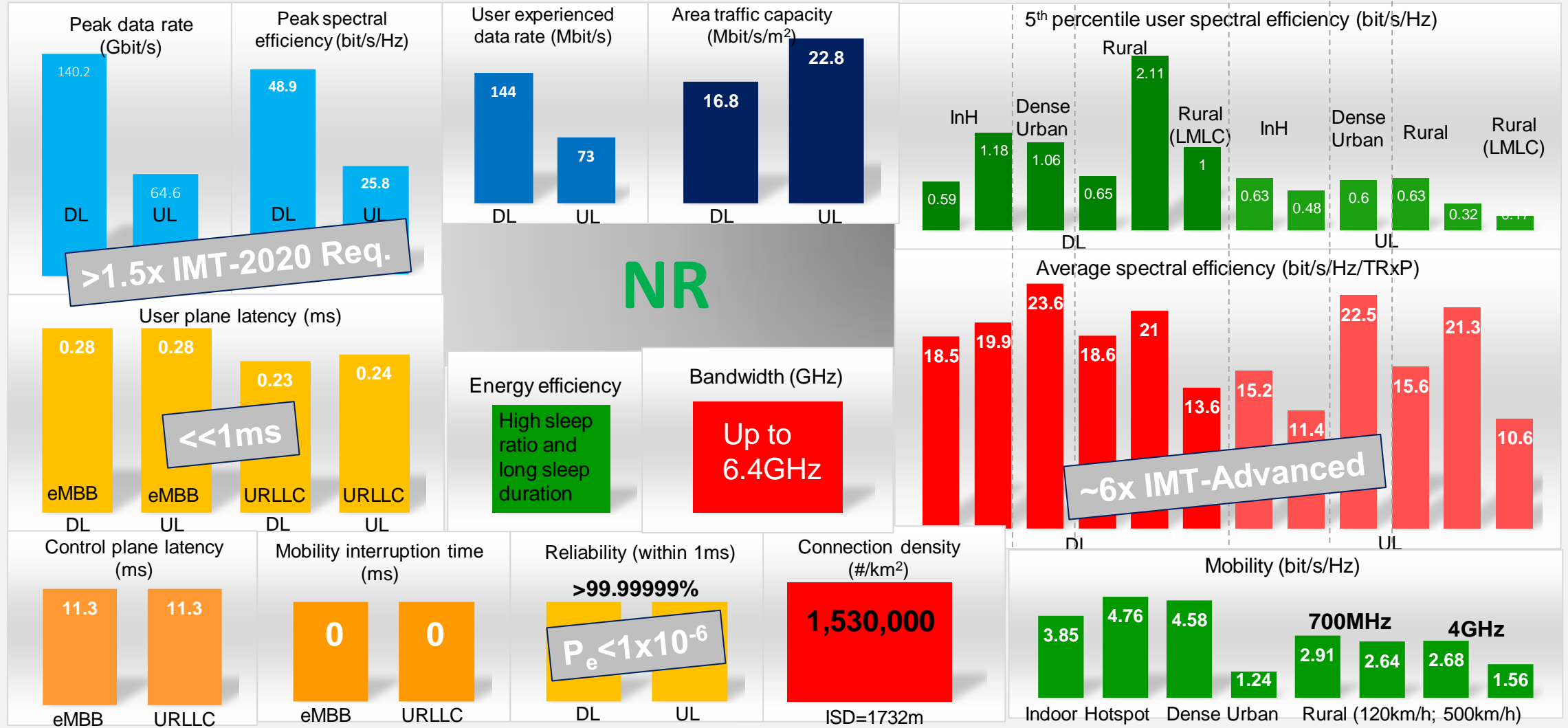
	Service capability requirements	SRIT (NR+LTE)	NR RIT
5.2.4.1.1	Support for wide range of services Is the proposal able to support a range of services across different usage scenarios (eMBB, URLLC, and mMTC)?: YES/NO Specify which usage scenarios (eMBB, URLLC, and mMTC) the candidate RIT or candidate SRIT can support.	YES <i>The SRIT can support eMBB, URLLC and mMTC usage scenarios.</i>	YES <i>The NR RIT can support eMBB, URLLC and mMTC usage scenarios.</i>
	Spectrum capability requirements	SRIT (NR+LTE)	NR RIT
5.2.4.2.1	Frequency bands identified for IMT Is the proposal able to utilize at least one frequency band identified for IMT in the ITU Radio Regulations?: YES /NO Specify in which band(s) the candidate RIT or candidate SRIT can be deployed.	YES <i>LTE RIT supports the IMT band from 450 MHz to 5925 MHz.</i> <i>NR RIT supports the IMT band from 663 MHz to 5000 MHz.</i> <i>See Section 5.2.3.2.8.3 in characteristics template for details.</i>	YES <i>NR RIT supports the IMT band from 663 MHz to 5000 MHz, including 3.3-3.8; 3.3-4.2 GHz.</i> <i>See Section 5.2.3.2.8.3 in characteristics template for NR RIT for details.</i>
5.2.4.2.2	Higher Frequency range/band(s) Is the proposal able to utilize the higher frequency range/band(s) above 24.25 GHz?: YES Specify in which band(s) the candidate RIT or candidate SRIT can be deployed. (NOTE 1)	YES <i>NR RIT supports 24.25-27.5; 27.5-28.35; 26.5-29.5; 37-40 GHz.</i>	YES <i>NR RIT supports 24.25-27.5; 27.5-28.35; 26.5-29.5; 37-40 GHz.</i>

NOTE 1 – In the case of the candidate SRIT, at least one of the component RITs need to fulfil this requirement.



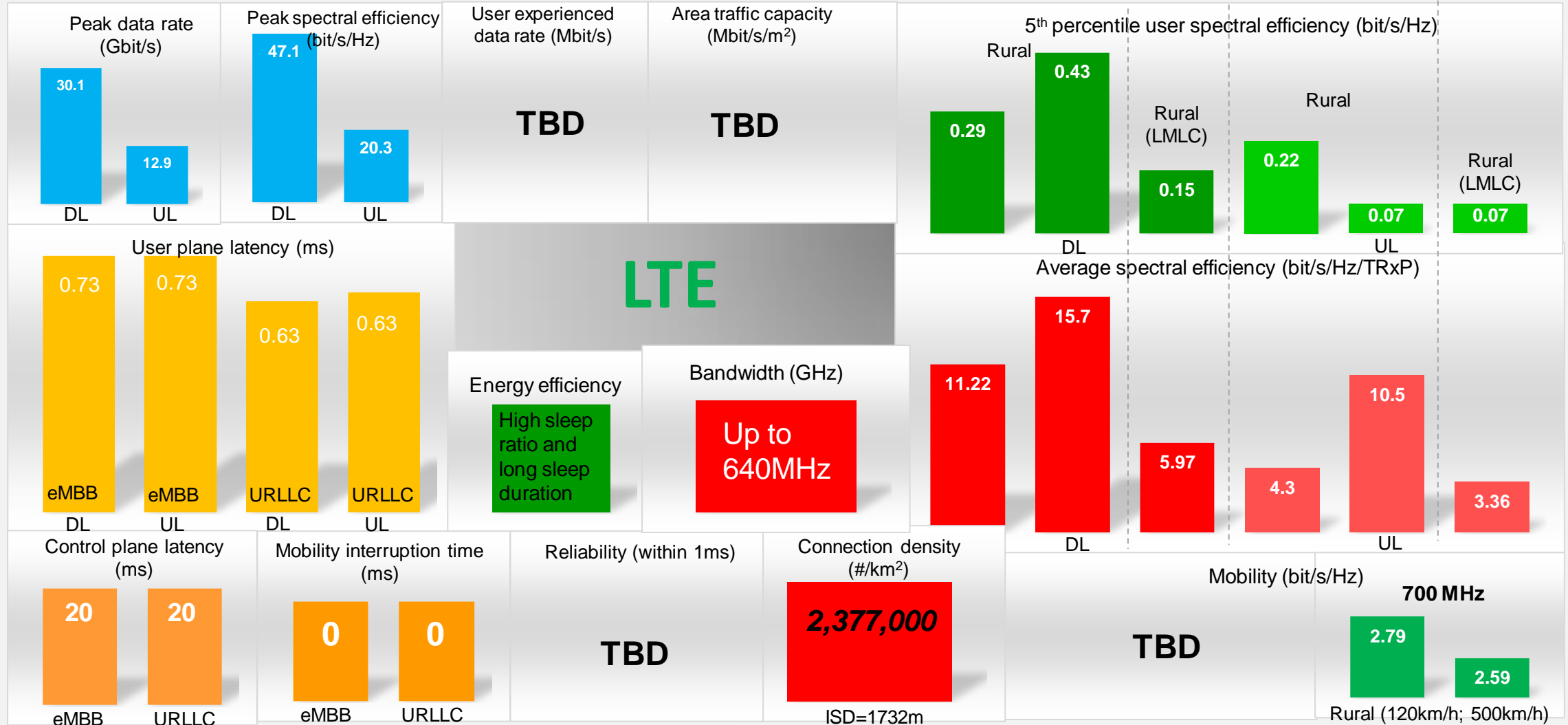
3GPP Compliance to Technical Performance Requirement

- For NR RIT, Rel-15 is evaluated; further update might be made before final submission



3GPP Compliance to Technical Performance Requirement

- For LTE RIT, Rel-15 is evaluated; further update might be made before final submission



3GPP Compliance to Technical Performance Requirement

Usage scenario	Sub-items	Evaluation method	Test environment				
			eMBB			mMTC	URLLC
			Indoor hotspot	Dense urban	Rural	Urban macro	Urban macro
eMBB	Peak data rate	Analysis					
	Peak spectral efficiency	Analysis					
	User experienced data rate	Analysis, or SLS (for multi-layer)					
	5 th percentile user spectral efficiency	SLS					
	Average spectral efficiency	SLS					
	Area traffic capacity	Analysis					
	Energy efficiency	Inspection					
	Mobility	SLS + LLS					
eMBB, URLLC	User plane latency	Analysis					
	Control plane latency	Analysis					
	Mobility interruption time	Analysis					
URLLC	Reliability	SLS + LLS					
mMTC	Connection density	SLS + LLS, or Full SLS					
General	Bandwidth and Scalability	Inspection					

Both 5G SRIT and NR RIT are compliant with all technical performance requirements

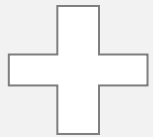
Summary

- 3GPP provided all necessary templates and preliminary self evaluation results towards IMT-2020 submission based on Rel-15 work.
- Preliminary evaluation shows that 3GPP 5G meets all IMT-2020 requirements.
- Independent evaluation groups are welcome to refer to these materials to prepare the evaluation activity.

Description templates

Characteristics templates (RP-182052)

- For SRIT (NR+LTE)
- For NR RIT

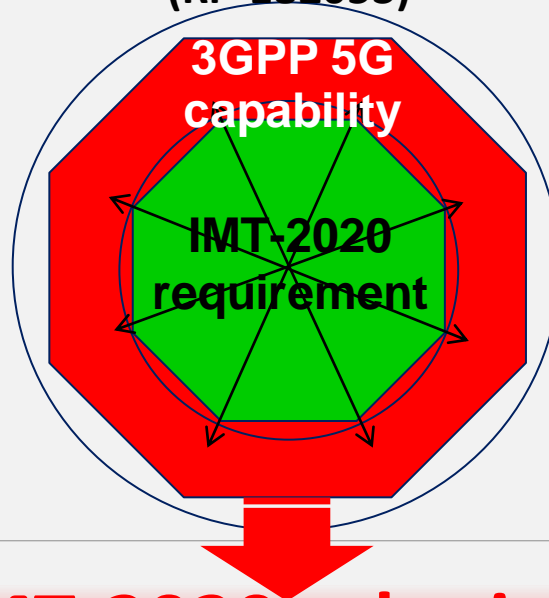


Link budget template (RP-182110)

- NR in 4 test environments,
- LTE in 2 test environments

Compliance templates

Compliance templates (RP-182053)



Self evaluation report TR37.910v1.0.0

- Based on evaluation guidelines defined in Report ITU-R M.2412.
- **Preliminary results for Rel-15**
 - ✓ **NR RIT:** 5 test environments for eMBB, URLLC and mMTC
 - ✓ **LTE RIT:** Rural – eMBB and Urban Macro – mMTC
 - ✓ May be further updated before final submission

IMT-2020 submission

Thanks to all contributors!



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THANK YOU

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IMT-2020 submission templates: Description characteristics template

Kazuaki Takeda
NTT DOCOMO, INC.

Characteristics templates for SRIT and RIT of “5G”



- Description template; one characteristics template for SRIT (encompassing NR and LTE), and one characteristics template for NR RIT (RP-182052)

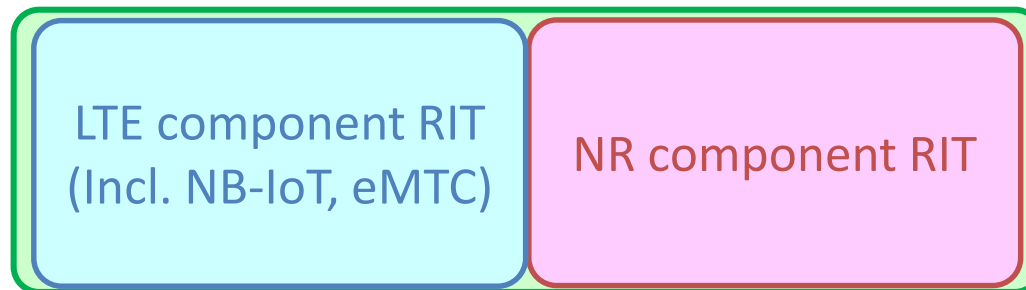
SRIT

- Component RIT: NR
- Component RIT: EUTRA/LTE (incl. standalone LTE, NB-IoT, eMTC, and LTE-NR DC)

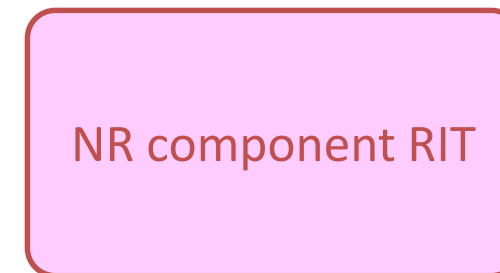
RIT

- NR RIT

SRIT → One template



RIT → One template



Contents of Description Template (27 Items)



- 5.2.3.2.1 Test environment(s)
- 5.2.3.2.2 Radio interface functional aspects
- 5.2.3.2.3 Describe channel tracking capabilities (e.g. channel tracking algorithm, pilot symbol configuration, etc.) to accommodate rapidly changing delay spread profile.
- 5.2.3.2.4 Physical channel structure and multiplexing
- 5.2.3.2.5 Mobility management (Handover)
- 5.2.3.2.6 Radio resource management
- 5.2.3.2.7 Frame structure
- 5.2.3.2.8 Spectrum capabilities and duplex technologies
- 5.2.3.2.9 Support of Advanced antenna capabilities
- 5.2.3.2.10 Link adaptation and power control
- 5.2.3.2.11 Power classes
- 5.2.3.2.12 Scheduler, QoS support and management, data services
- 5.2.3.2.13 Radio interface architecture and protocol stack
- 5.2.3.2.14 Cell selection
- 5.2.3.2.15 Location determination mechanisms
- 5.2.3.2.16 Priority access mechanisms
- 5.2.3.2.17 Unicast, multicast and broadcast
- 5.2.3.2.18 Privacy, authorization, encryption, authentication and legal intercept schemes
- 5.2.3.2.19 Frequency planning
- 5.2.3.2.20 Interference mitigation within radio interface
- 5.2.3.2.21 Synchronization requirements
- 5.2.3.2.22 Link budget template
- 5.2.3.2.23 Support for wide range of services
- 5.2.3.2.24 Global circulation of terminals
- 5.2.3.2.25 Energy efficiency
- 5.2.3.2.26 Other items
- 5.2.3.2.27 Other information

3GPP provided description for most items
→ Describe items related to evaluations

Test environment and radio interface functionality



- 5.2.3.2.1 Test environment(s)
 - Cover 5 test environments across eMBB, URLLC, mMTC usage cases
- 5.2.3.2.2 Radio interface functional aspects
 - Describe multiple access, modulation, error coding schemes, etc.

Items	NR	LTE
Multiple access schemes	DL: CP-OFDM <ul style="list-style-type: none">Spectral confinement techniques transparent to receiver UL: <u>CP-OFDM</u> and DFT-s-OFDM	DL: CP-OFDM UL: DFT-s-OFDM
Error coding schemes	LDPC for data channel Polar coding for control channel	Turbo coding for data channel Convolutional coding for control channel

RS and channel structure

5.2.3.2.3 Describe channel tracking capabilities

- Reference signal (RS) to support channel tracking are listed for NR and LTE (next slide)

5.2.3.2.4 Physical channel structure and multiplexing

- Describe physical channel bit rate, L1/L2 overhead, etc.

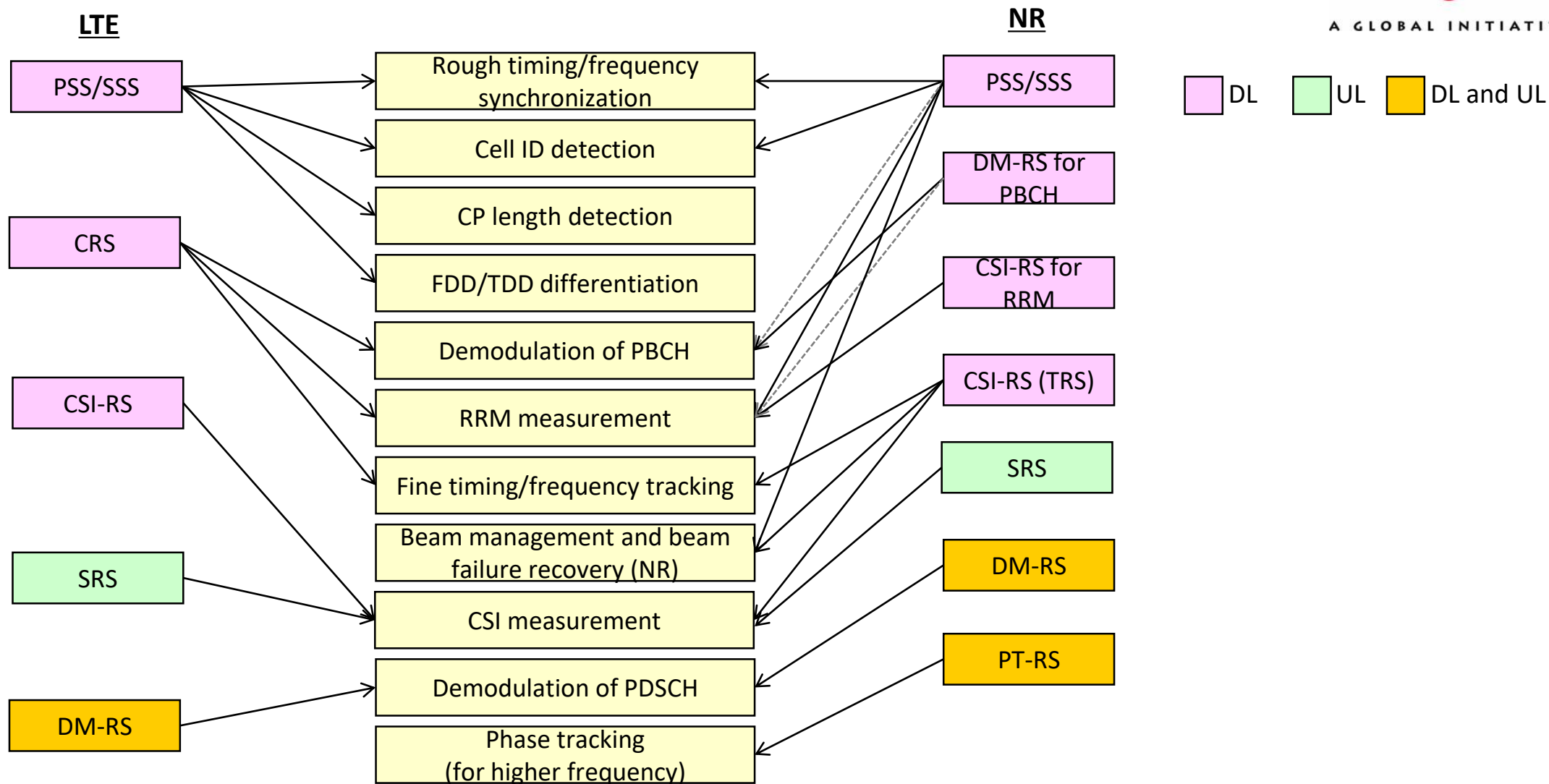
Example of RS overhead calculation

Reference signal type	Example configurations	Overhead for example configurations
DMRS-PDSCH	As examples, DMRS can occupy 1/3, 1/2, or one full OFDM symbol. 1, 2, 3 or 4 symbols per slot can be configured to carry DMRS.	2.4 % to 29 %
PTRS- PDSCH	1 resource elements in frequency domain every second or fourth resource block. PTRS is mainly intended for FR2.	0.2% or 0.5 % when configured.
CSI-RS	1 resource element per resource block per antenna port per CSI-RS periodicity	0.25 % for 8 antenna ports transmitted every 20 ms with 15 kHz subcarrier spacing
TRS	2 slots with 1/2 symbol in each slot per transmission period	0.36 % or 0.18% respectively for 20 ms and 40ms periodicity





Example of SS and RS Structure






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5.2.3.2.5 Mobility management (Handover)

-  1) Intra-NR handover: Network controlled mobility for UEs in RRC_CONNECTED
 -  Cell level mobility (Handover)
 -  Beam level mobility (at lower layers)
 - Measurement of multiple beams of a cell
-  2) Inter-RAT handover: Intra 5GC inter RAT mobility between NR and E-UTRA

5.2.3.2.6 Radio resource management

-  Multi-RAT dual connectivity (MR-DC): Tight inter-working between E-UTRA and NR
 -  MR-DC with the EPC
 - E-UTRA-NR Dual Connectivity (EN-DC). eNB is master node (MN) and gNB is secondary node (SN)
 -  MR-DC with the 5GC:
 - NG-RAN E-UTRA-NR Dual Connectivity (NGEN-DC): eNB is MN and gNB is SN
 - NR-E-UTRA Dual Connectivity (NE-DC): gNB is MN and eNB is SN

Frame structure and spectrum aspects



5.2.3.2.7 Frame structure



NR supports the following scalable numerologies and slot structure



5.2.3.2.8 Spectrum capabilities and duplex technologies

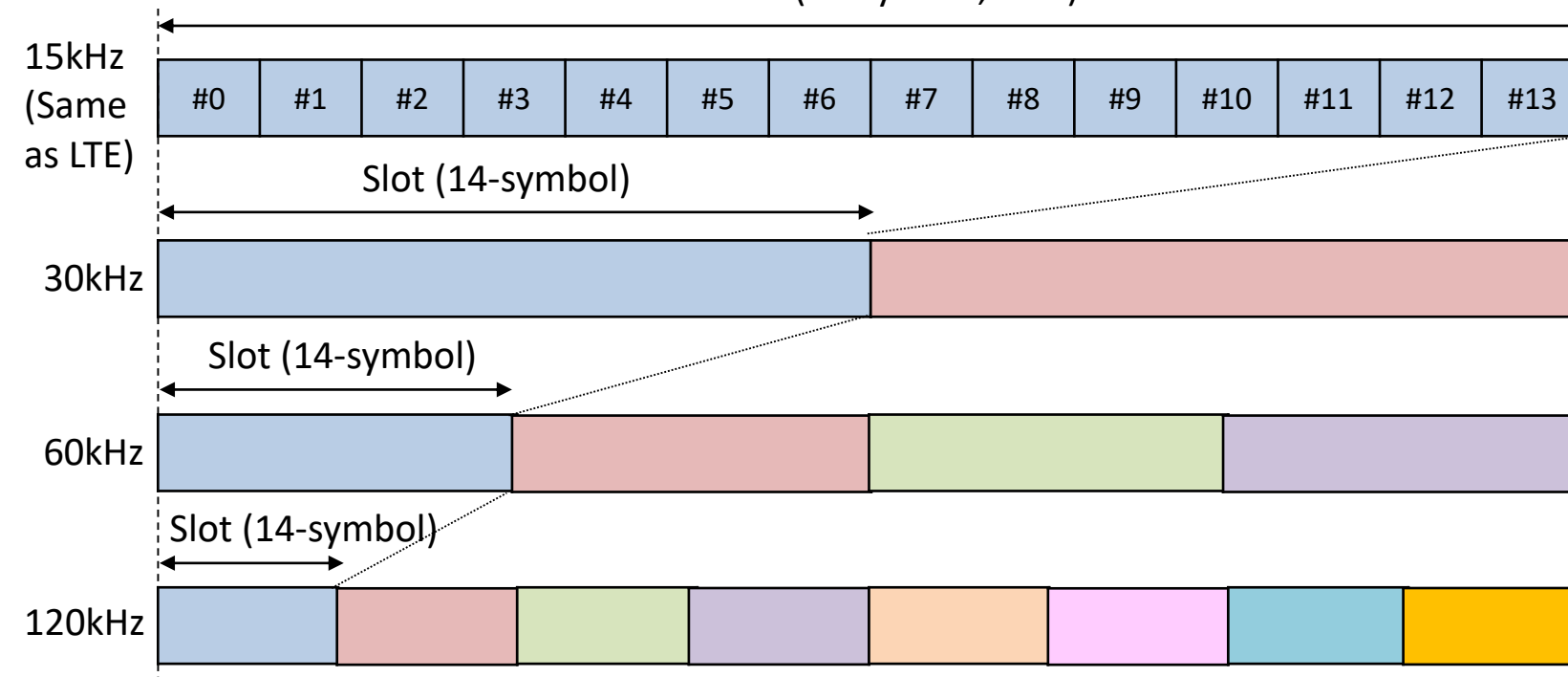


NR supports flexible spectrum use through, CA, BWP, SUL and co-existence with LTE-M/NB-IoT



NR supports scalable bandwidth of up to 100MHz for FR1 and 400MHz for FR2

Slot (14-symbol, 1ms)



SCS [kHz]	No. of symbols per slot	No. of slots per subframe	No. of subframes per radio frame
15	14	1	10
30	14	2	10
60	14	4	10
120	14	8	10

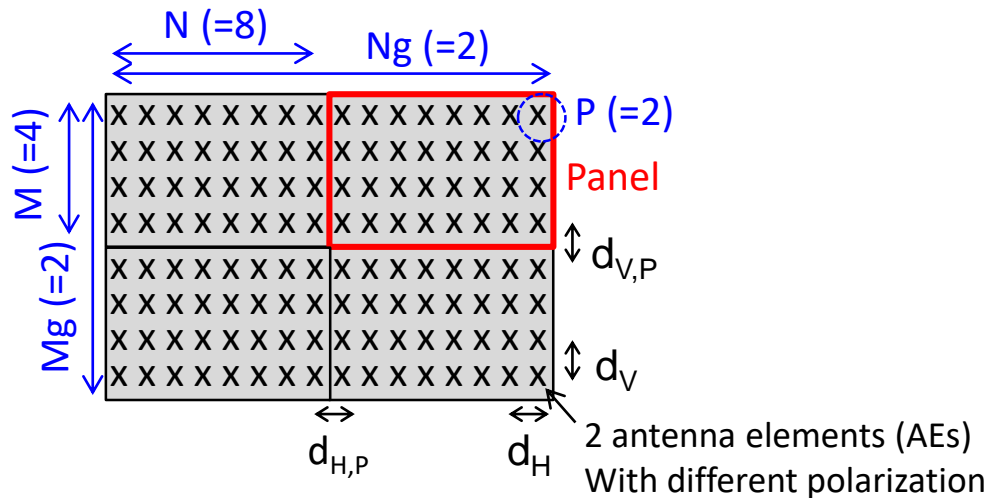
Note: this is for normal CP.

For SCS 60kHz, extended CP is supported.

For ECP, no. of symbols per slot is 12.

MIMO and link adaptation

- 5.2.3.2.9 Support of Advanced antenna capabilities
 - NR/LTE: Enabling hybrid beamforming including both digital and analog beamforming
 - NR/LTE: Up to 32 antenna ports for DL and up to 4 antenna ports for UL
- 5.2.3.2.10 Link adaptation and power control
 - NR/LTE: Link adaptation based on Channel State information (CSI) reported from UE
 - NR/LTE: Both open-loop and closed-loop power control are supported





Example of MIMO antenna

MIMO layers for spatial multiplexing









		Rel. 14/15 LTE	NR
DL	SU-MIMO	Max 8 layers	Max 8 layers
	MU-MIMO	Max 8 layers (orthogonal/ non-orthogonal DM-RS)	Max 12 layers (orthogonal DM-RS)
UL	SU-MIMO	Max 4 layers	Max 4 layers

Power class and scheduling

5.2.3.2.11 Power classes

-  For NR, 2 power classes for FR1 and 4 power classes for FR2 are specified
 -  For FR2, the maximum output power radiated by the UE for any transmission bandwidth of NR carrier is defined as TRP (Total Radiated Power) and EIRP (Equivalent Isotropically Radiated Power)

5.2.3.2.12 Scheduler, QoS support and management, data services

-  Scheduling, e.g., proportional fair algorithm, may be performed based on CSI reporting
-  NR also supports following features related to scheduling
 -  Semi-persistent scheduling
 -  UL configured grant transmission
 -  Slot aggregation
 -  Dynamic DL/UL allocation for TDD
 -  MCS with low code rate
 -  Pre-emption

Frequency planning, interference mitigation and synchronization



- 5.2.3.2.19 Frequency planning
 - 1008 physical cell IDs for NR and 504 physical cell IDs
- 5.2.3.2.20 Interference mitigation within radio interface
 - NR/LTE support coordinated multipoint transmission/reception (CoMP)
 - NR further supports, for reducing inter-cell interference,
 - Longer periodicities of synchronization signal blocks (SSBs)
 - UE-specific RSs for control/data channels that are only transmitted
 - Configurable frequency-domain control channel resources
- 5.2.3.2.21 Synchronization requirements
 - NR/LTE performs almost the same procedures, i.e., based on primary synchronization signal (PSS) and secondary synchronization signal (SSS)
 - PSS: Initial symbol boundary, cyclic prefix, subframe boundary, initial frequency synchronization.
 - SSS: Radio frame boundary identification
 - Note: PSS and SSS together used for cell ID detection

Energy efficiency

5.2.3.2.25 Energy efficiency

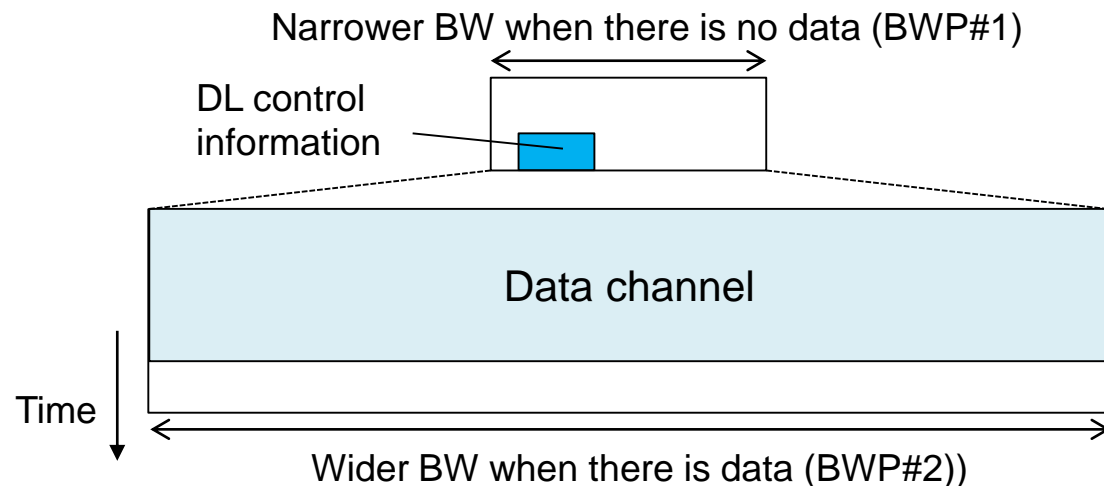
Network energy efficiency

- Related to always-on transmissions, i.e., SSB → See details in TR37.910

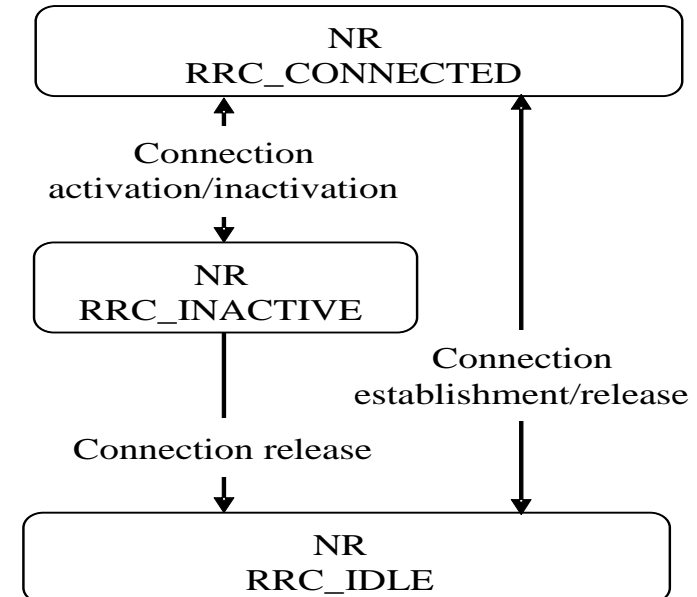
Device energy efficiency

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

Ex). BWP adaptation



NR RRC state



Summary

- Describe overview of characteristics template
 - 📶 Description template is separately drafted for SRIT and RIT
 - SRIT: NR Component RIT + LTE component RIT
 - RIT: NR RIT
- Describe new and key functionalities that are the basis for ITU evaluation
 - 📶 Current template provided detailed descriptions of SRIT and RIT for most of 27 items
 - 📶 Will continue to be updated until the final submission

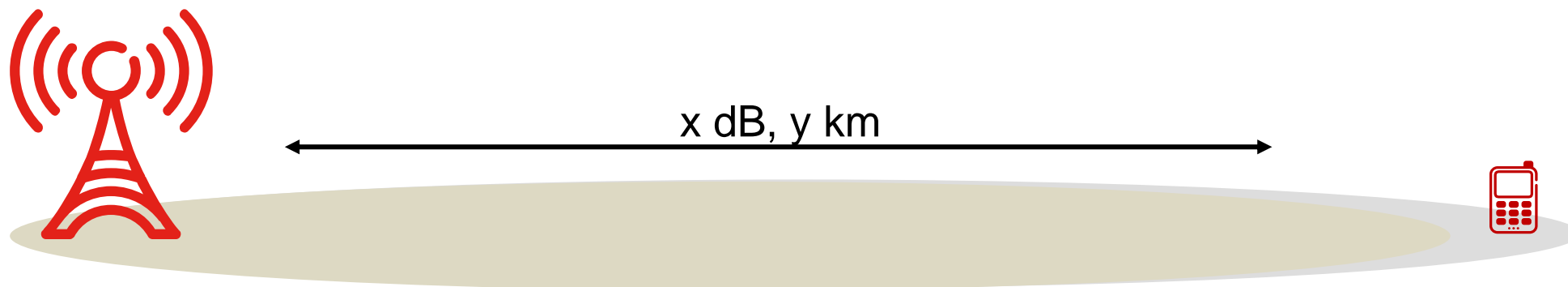


IMT-2020 submission templates: Link budget template

Asbjörn Grövlén
Ericsson

Link budget – what is it?

- Assess the maximum supported path loss and range
 - Downlink and uplink
 - Data and control
 - Five test environments: indoor hotspot eMBB, dense urban eMBB, rural eMBB, urban macro mMTC, urban macro URLLC



Guidelines from the ITU



TABLE 1

Link budget template for Indoor Hotspot-eMBB

Item	Downlink	Uplink
System configuration		
Carrier frequency (GHz)	4 or 30 or 70	4 or 30 or 70
BS antenna heights (m)	3	3
UE antenna heights (m)	1.5	1.5
Cell area reliability ⁽¹⁾ (%) (Please specify how it is calculated.)		
Transmission bit rate for control channel (bit/s)		
Transmission bit rate for data channel (bit/s)		

$= (90) + (11) - (220)$ dB		
Calculation of available pathloss		
(24) Lognormal shadow fading std deviation (dB)		
(25) Shadow fading margin (function of the cell area reliability and (24)) (dB)		
(26) BS selection/macro-diversity gain (dB)		
(27) Penetration margin (dB)		
(28) Other gains (dB) (if any please specify)		
(29a) Available path loss for control channel $= (23a) - (25) + (26) - (27) + (28) - (12)$ dB		
(29b) Available path loss for data channel $= (23b) - (25) + (26) - (27) + (28) - (12)$ dB		
Range/coverage efficiency calculation		
(30a) Maximum range for control channel (based on (29a) and according to the system configuration section of the link budget) (m)		
(30b) Maximum range for data channel (based on (29b) and according to the system configuration section of the link budget) (m)		
(31a) Coverage Area for control channel $= (\pi (30a)^2)$ (m ² /site)		
(31b) Coverage Area for data channel $= (\pi (30b)^2)$ (m ² /site)		

Methodology and tables provided in M.2111, 5.2.3.3

One table per test environment

Indoor hotspot, dense urban, rural, urban macro mMTC, urban macro URLLC

Some parameters given by the ITU

Some parameters provided by proponent

Assumptions

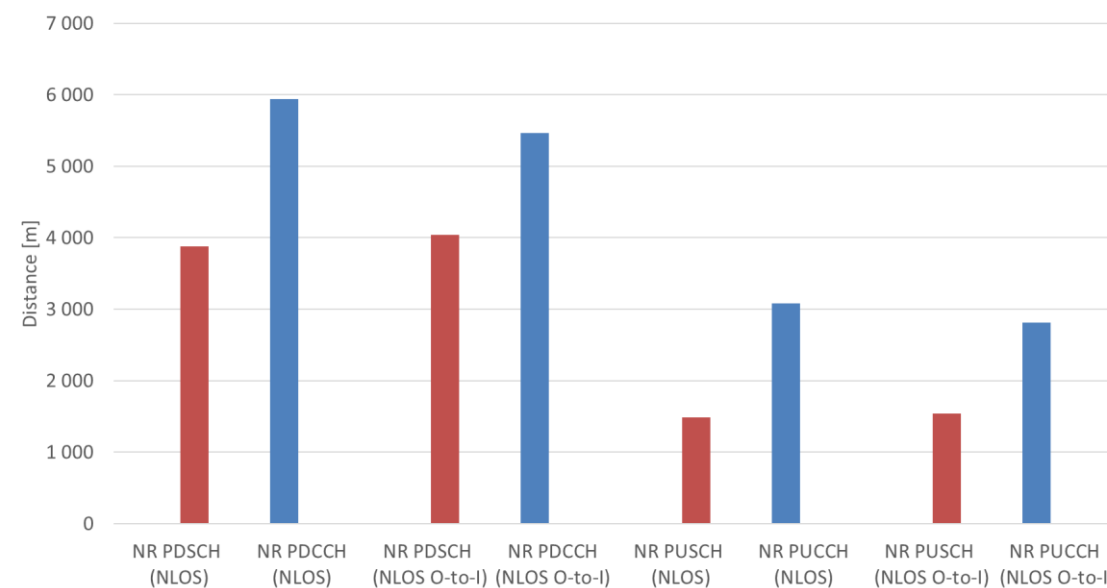
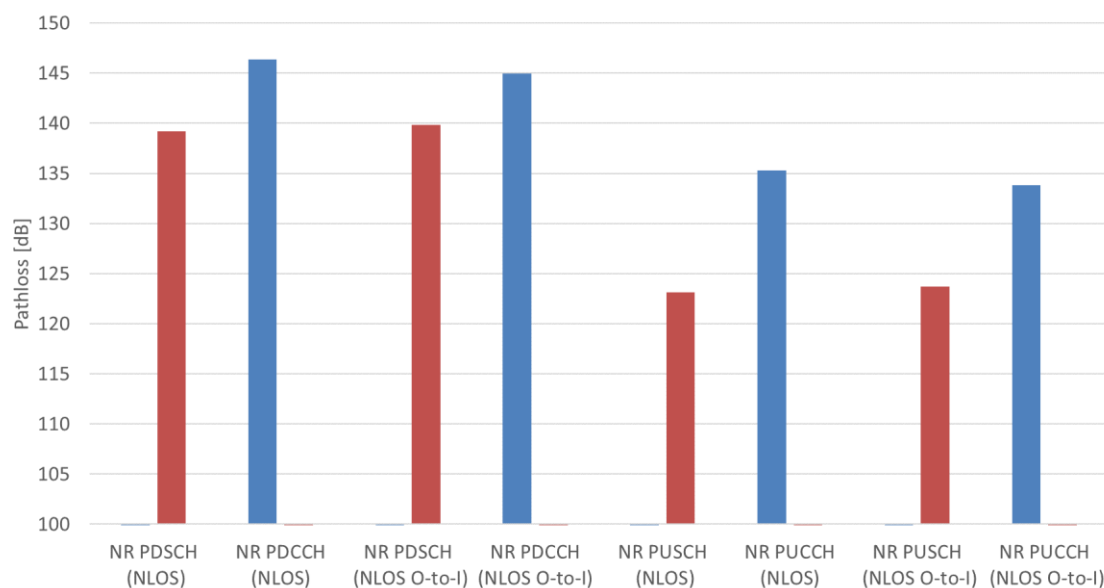
Simulation results

Assumptions from 3GPP

- NR and LTE
- Data represented by PDSCH and PUSCH
- Control represented by PDCCH (indicating downlink and uplink resource allocation, modulation and coding) and PUCCH (used for ACK/NACK, scheduling requests, channel quality indication)
- For NR TDD, a DDDSU pattern is assumed for downlink and a DSUUD pattern for uplink
- Power levels, bandwidths, noise figures, antenna configurations aligned with test environment configurations
- Shadow fading and interference margins assumptions
- Link performance simulated
- Link: [RP-182097](#)

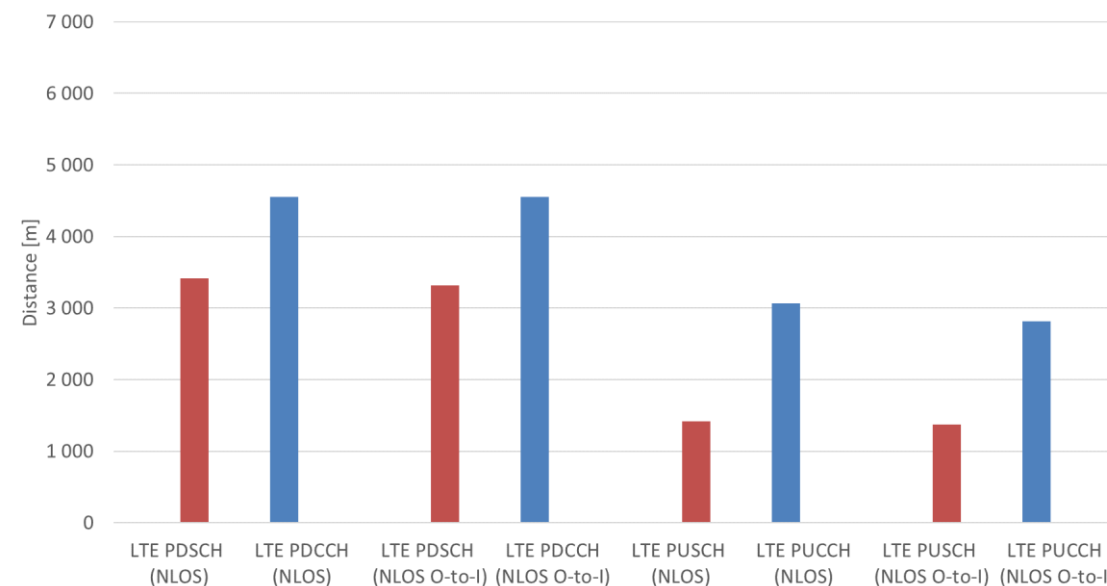
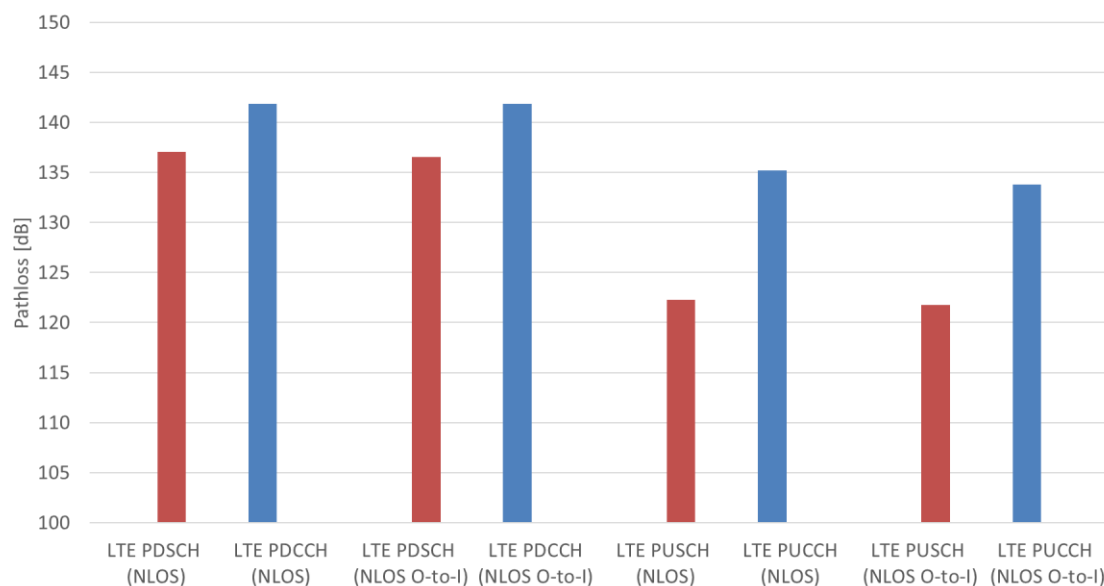
Preliminary results from 3GPP

- 🌿 Full results provided in [RP-182097](#)
- 🌿 Example, NR FDD 700MHz, rural, channel model A, 6Mbps DL, 0.5Mbps UL



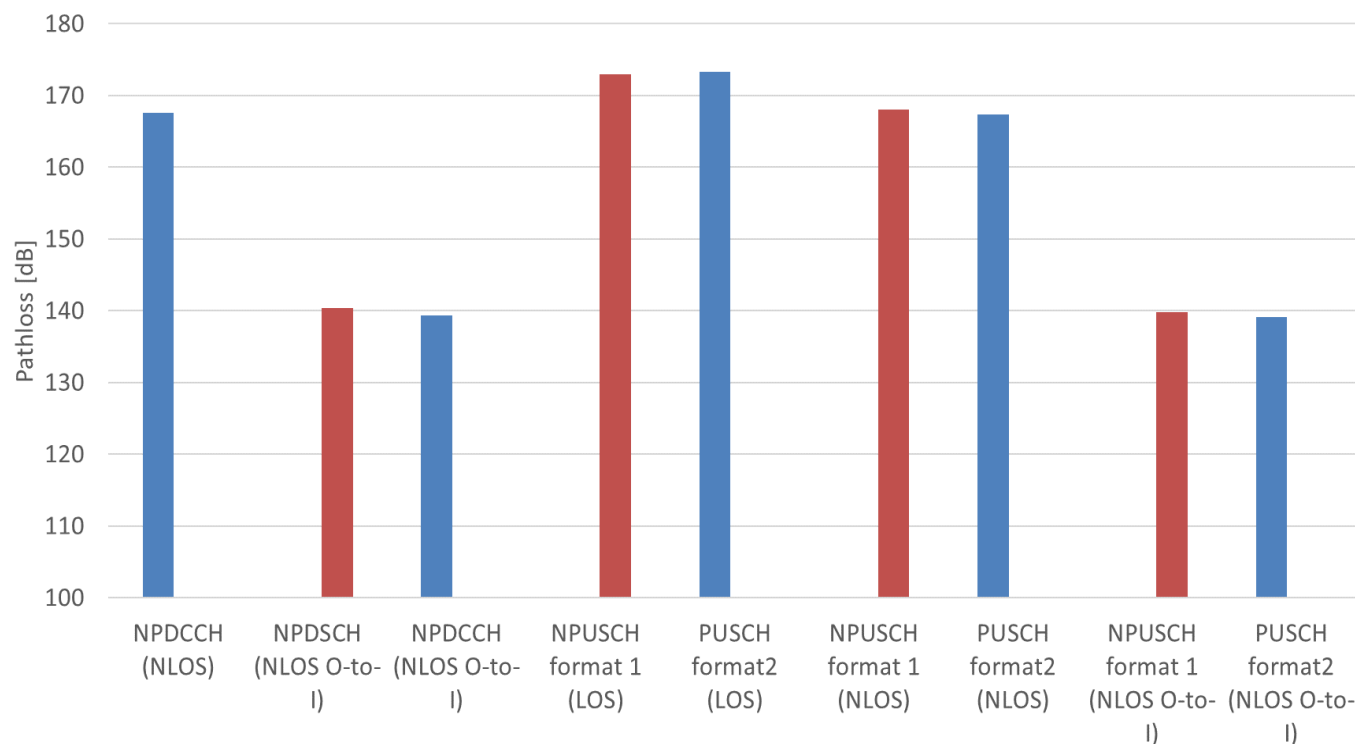
Preliminary results from 3GPP

- Full results provided in [RP-182097](#)
- Example, LTE FDD 700MHz, rural, channel model A, 6Mbps DL, 0.5Mbps UL



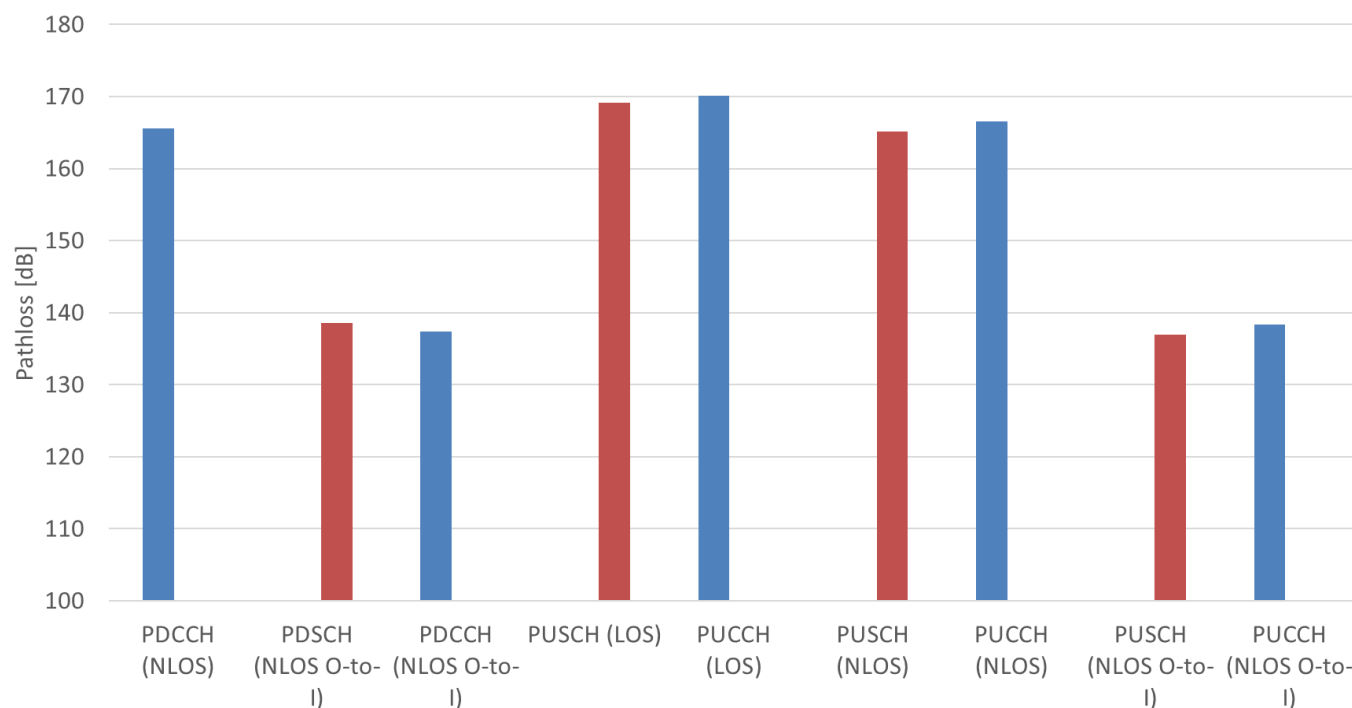
Preliminary results from 3GPP

- Full results provided in [RP-182097](#)
- Example, NB-IoT Uma-mMTC



Preliminary results from 3GPP

- Full results provided in [RP-182097](#)
- Example, eMTC, Uma-mMTC



What to do for the evaluation groups?

- Verify that parameters are aligned with ITU guidelines
- Verify that margins for fading and interference etc. are reasonable
- Verify link performance





RWS-180017

3GPP RAN Workshop on 3GPP
submission towards IMT-2020

Brussels, Belgium, 24-25 October 2018

A decorative graphic on the left side of the slide, consisting of a series of green circles of varying sizes arranged in a curved, descending path. Each circle contains a white icon: a 5G signal wave, a cloud, a network diagram, a cloud, a binary code "1010", a download arrow, a globe, a padlock, an envelope, and a small triangle.

Self-Evaluation: Calibration method and results

Source: Qualcomm
(Francesco Pica)

Self-Evaluation: Simulations Calibration

- Initial simulators calibration has been performed, for results' alignment
 - ~20 companies contributed: *CATR, CATT, CEWiT, China Telecom, China Mobile, Ericsson, Huawei, Intel, ITRI, LG Electronics, Mediatek, Motorola/Lenovo, NEC, Nokia, DOCOMO, OPPO, Qualcomm, Samsung, Sharp, vivo, ZTE.*
- The calibration was conducted for all Test Environments and evaluation configurations (for both channel model A and B)
- Two metrics were selected for initial calibration:
 - DL Geometry (SINR), Coupling gain

Calibration phase – Timelines & Outcomes

Sept. 2017 (RAN#77)

- Calibration phase started (over RAN ITU-R Ad-Hoc email reflector)

Dec. 2017 (RAN#78)

- [RP-172728](#): Initial summary of email discussion
- Calibration phase extended till Feb '18

.....


Mar. 2018 (RAN/SA#79)

- [RP-180524](#): Final summary of calibration results (also captured in TR 37.910)
- A Letter ([SP-180248](#)) was sent out to *WP5D and all Independent Evaluation Groups (IEGs)*, informing about the completion of the Calibration phase (summary&results enclosed), and advertising the future 3GPP WS (Oct'18)

Calibration Results - Overview

Test environment	Evaluation configuration	Calibration results (CM/TRxPs)
Indoor Hotspot - eMBB	Config. A (4 GHz)	Channel model A, 12&36 TRxP
		Channel model B, 12&36 TRxP
	Config. B (30 GHz)	Channel model A/B, 12&36 TRxP
	Config. C (70 GHz)	Channel model A/B, 12&36 TRxP
Dense Urban - eMBB	Config. A (4 GHz)	Channel model A
		Channel model B
	Config. B (30 GHz)	Channel model A/B
Rural - eMBB	Config. A (1732 m, 700 MHz)	Channel model A
		Channel model B
	Config. B (1732 m, 4 GHz)	Channel model A
		Channel model B
	Config. C (LMLC, 6000 m, 700 MHz)	Channel model A
		Channel model B
Urban Macro - mMTC	Config. A (500 m, 700 MHz)	Channel model A
		Channel model B
	Config. B (1732 m, 700 MHz)	Channel model A
		Channel model B
Urban Macro - URLLC	Config. A (4 GHz)	Channel model A
		Channel model B
	Config. B (700 MHz)	Channel model A
		Channel model B

Ref: specific calibration parameters and assumptions for each TE/configuration, and detailed results, are captured in RP-180524 (sec. 4).

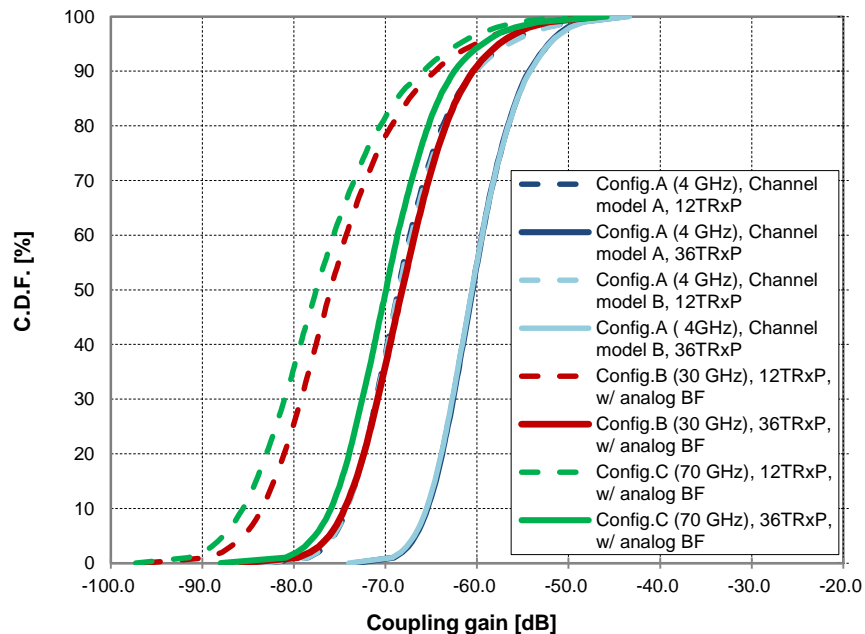
The results/plots shown in next slides are based on the average of the individual results (from different companies)... 

Calibration Results Summary

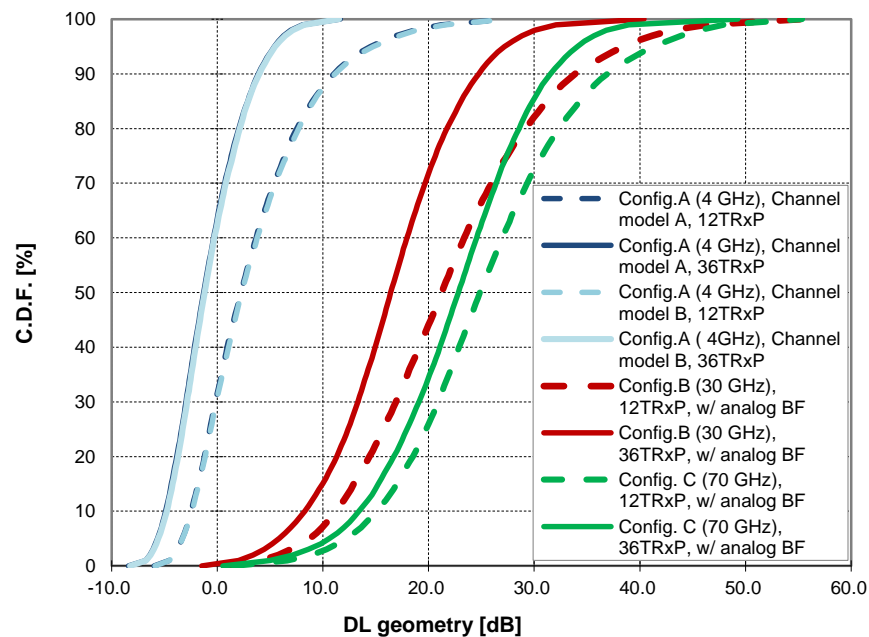
Indoor Hotspot - eMBB



Coupling Gain



DL Geometry

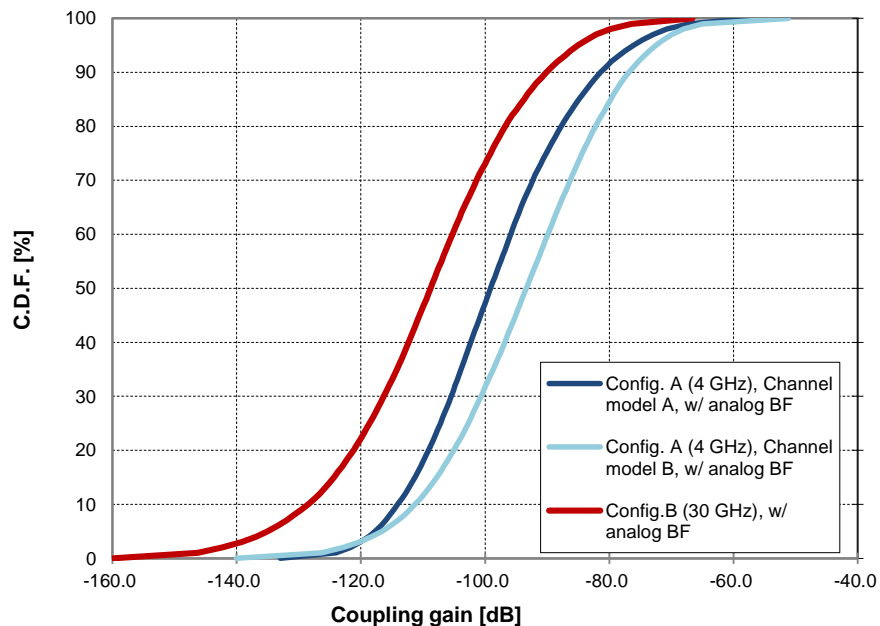


Calibration Results Summary

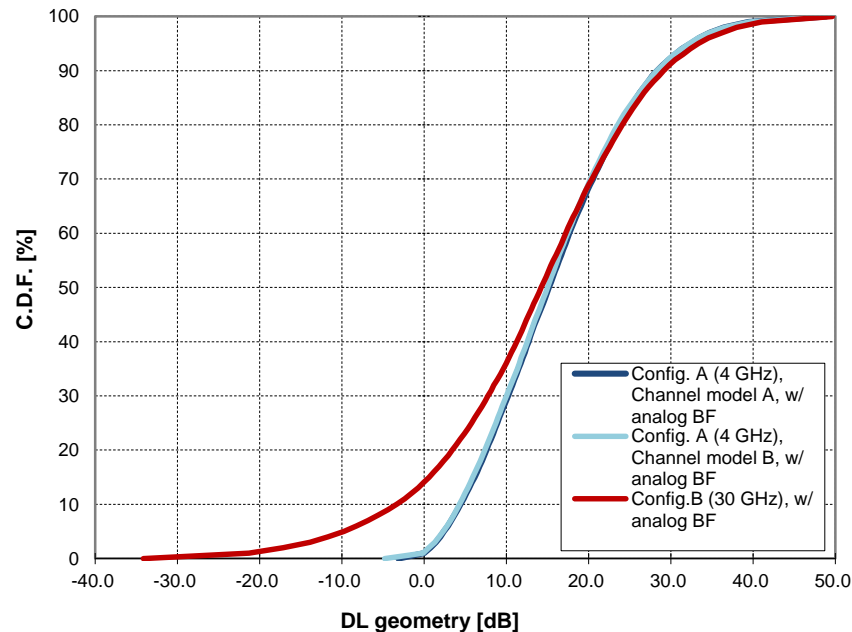
Dense Urban - eMBB



Coupling Gain



DL Geometry

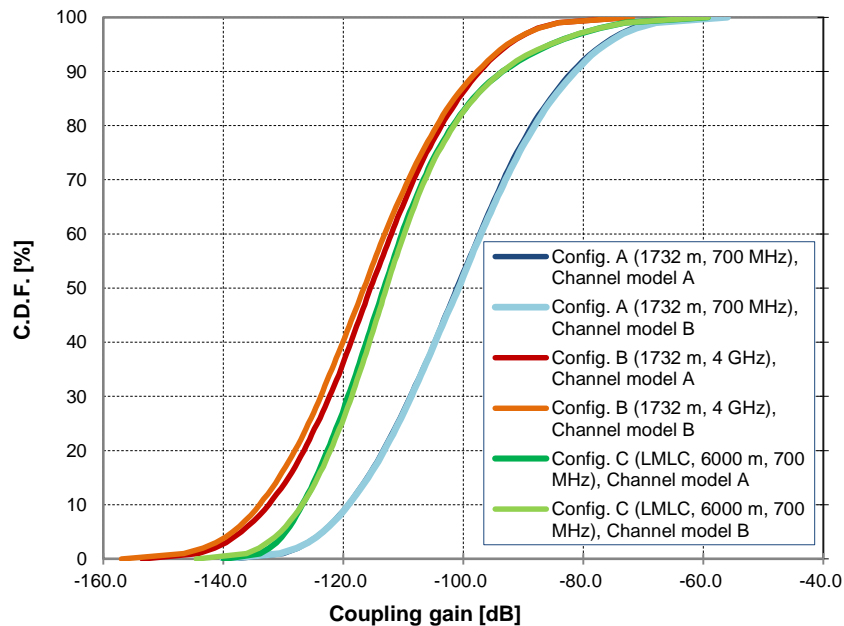


Calibration Results Summary

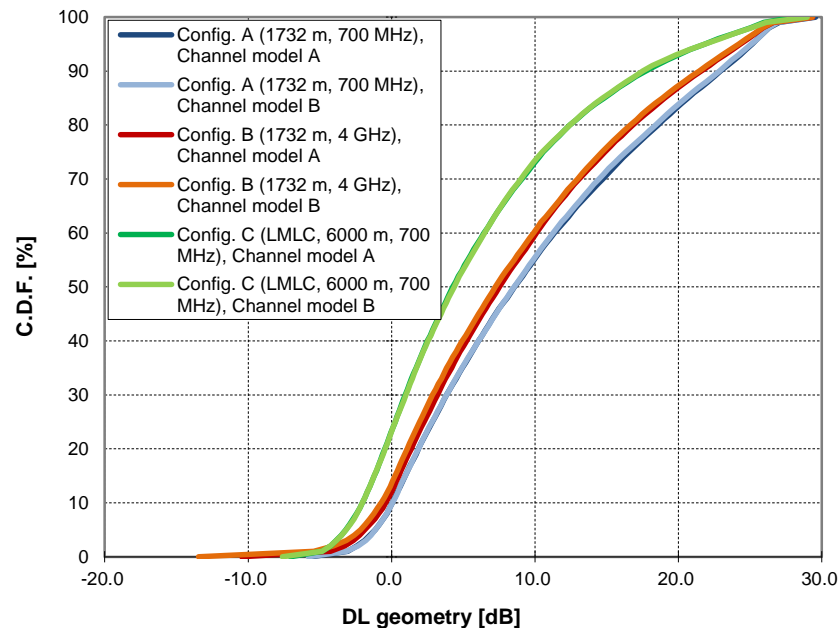
Rural - eMBB



Coupling Gain



DL Geometry

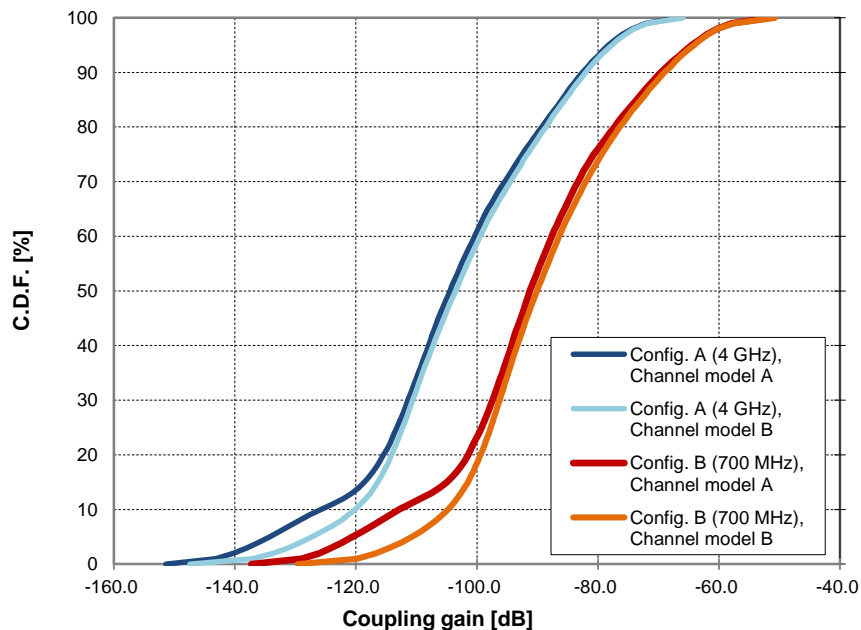


Calibration Results Summary

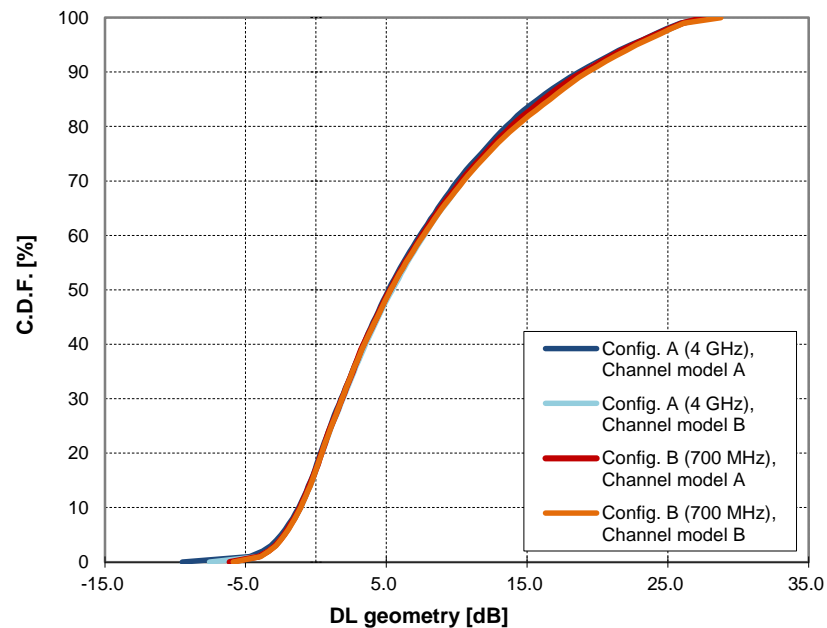
Urban Macro - URLLC



Coupling Gain



DL Geometry

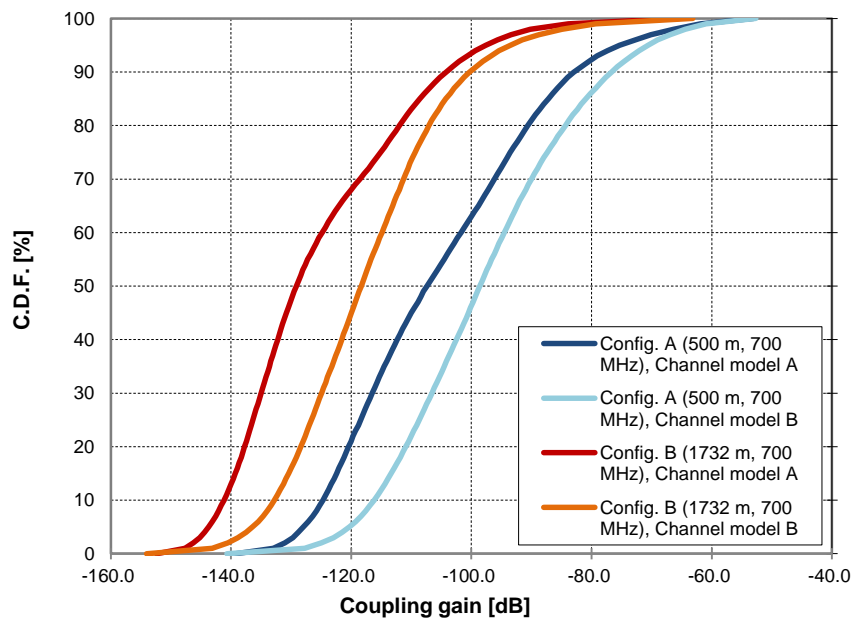


Calibration Results Summary

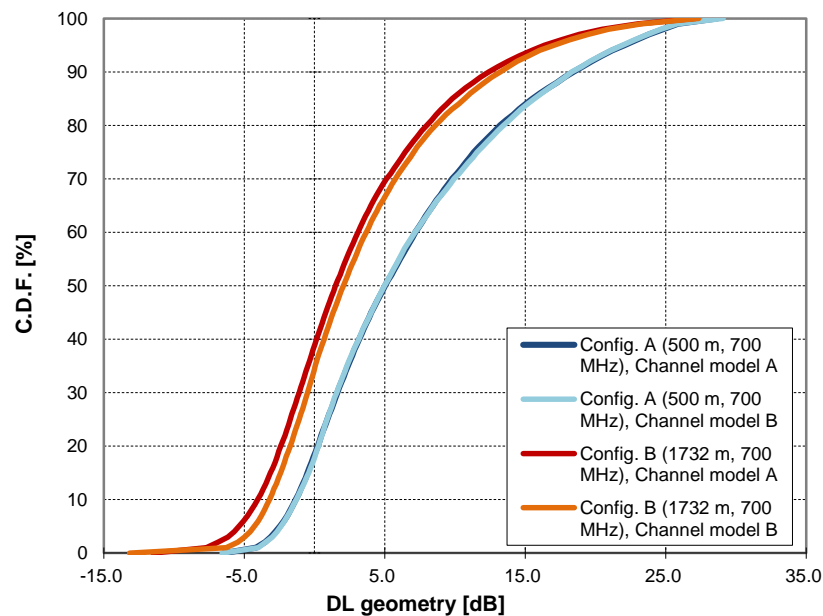
Urban Macro - mMTC



Coupling Gain



DL Geometry



Conclusions

 Calibration for IMT-2020 self-evaluation shows good results' alignment

- E.g. DL geometry/SINR results are typically within 1-2 dB of the average SINR

Test environment	Evaluation configuration	Channel model / Topology		Number of samples	DL SINR diff. vs Avg SINR (50%-tile CDF)
Indoor Hotspot - eMBB	Config. A (4 GHz)	Channel model A	12TRxP	16	<0.8 dB
			36TRxP	15	<0.5 dB
		Channel model B	12TRxP	18	<0.9 dB
			36TRxP	16	<0.4 dB
	Config. B (30 GHz)	Channel model A/B	12TRxP	17	<2.2 dB
			36TRxP	14	<2.2 dB
Dense Urban - eMBB	Config. C (70 GHz)	Channel model A/B	12TRxP	16	<1.6 dB
			36TRxP	12	<1.9 dB
	Config. A (4 GHz)	Channel model A		16	<1.3 dB
Rural - eMBB	Config. A (1732 m, 700 MHz)	Channel model B		18	<1.3 dB
		Channel model A/B		18	<2.4 dB
	Config. B (1732 m, 4 GHz)	Channel model A		18	<0.8 dB
		Channel model B		20	<0.9 dB
		Channel model A		18	<0.9 dB
		Channel model B		20	<1.2 dB
Urban Macro - mMTC	Config. C (LMLC, 6000 m, 700 MHz)	Channel model A		15	<0.9 dB
		Channel model B		16	<1.0 dB
	Config. A (500 m, 700 MHz)	Channel model A		15	<0.9 dB
		Channel model B		16	<0.6 dB
	Config. B (1732 m, 700 MHz)	Channel model A		15	<1.2 dB
		Channel model B		16	<0.6 dB
Urban Macro - URLLC	Config. A (4 GHz)	Channel model A		15	<0.9 dB
		Channel model B		17	<1.0 dB
	Config. B (700 MHz)	Channel model A		15	<0.9 dB
		Channel model B		16	<1.3 dB

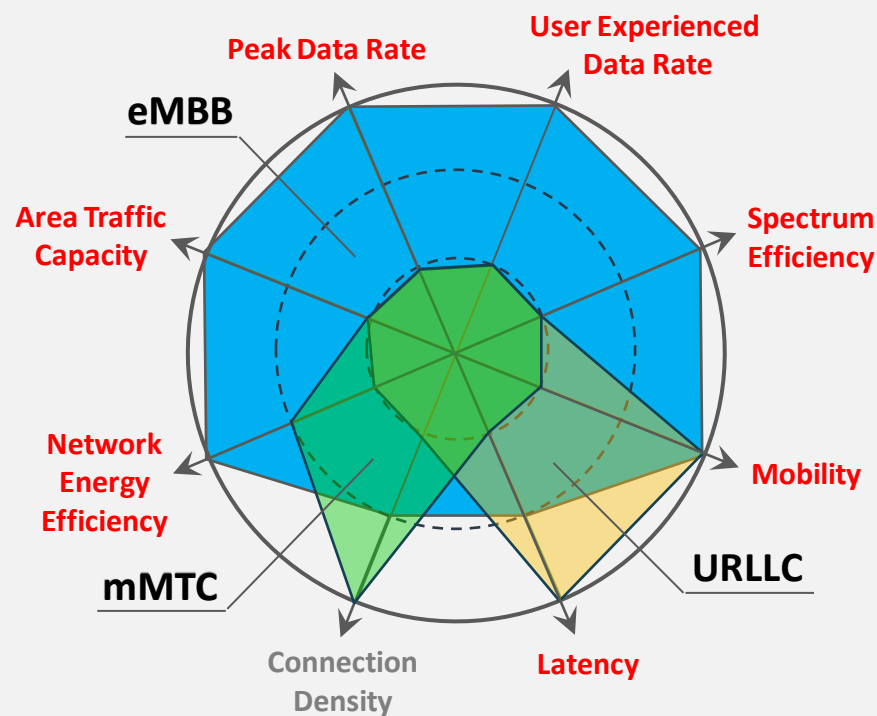
Thank you!

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 (5 th percentile user data rate)	100 Mbit/s	50 Mbit/s	-
5 th 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 (5 th percentile user data rate)	Analysis, or <i>SLS</i>		NR	
5 th percentile user spectral efficiency	<i>SLS</i>	NR	NR	NR, LTE
Average spectral efficiency	<i>SLS</i>	NR	NR	NR, LTE
Area traffic capacity	Analysis	NR		
Energy efficiency	Inspection	NR, LTE		
Mobility class With traffic channel link data rates	<i>SLS</i> + <i>LLS</i>	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%

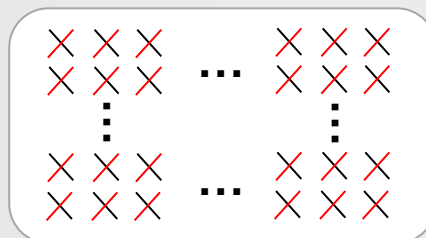
- NR Multiple SCSs enable reduced slot durations

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

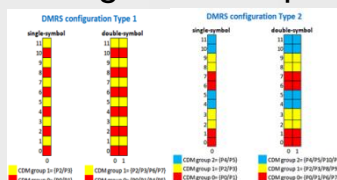
- NR PDCCH and PDSCH sharing allows overhead reduction, especially in large CC bandwidth

Massive MIMO

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



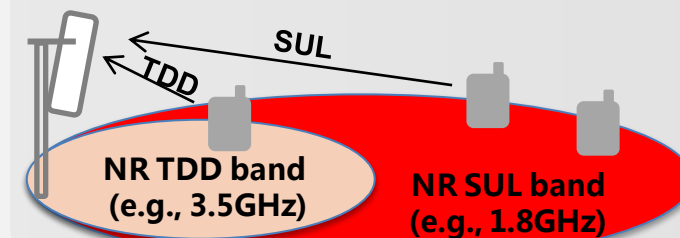
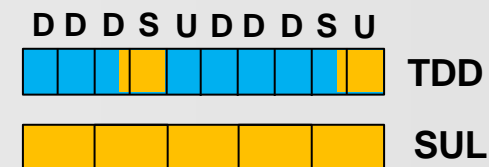
- NR supports 12 orthogonal DM-RS ports for MU pairing. LTE supports 4 orthogonal UE specific RS ports



- 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



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)



- 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

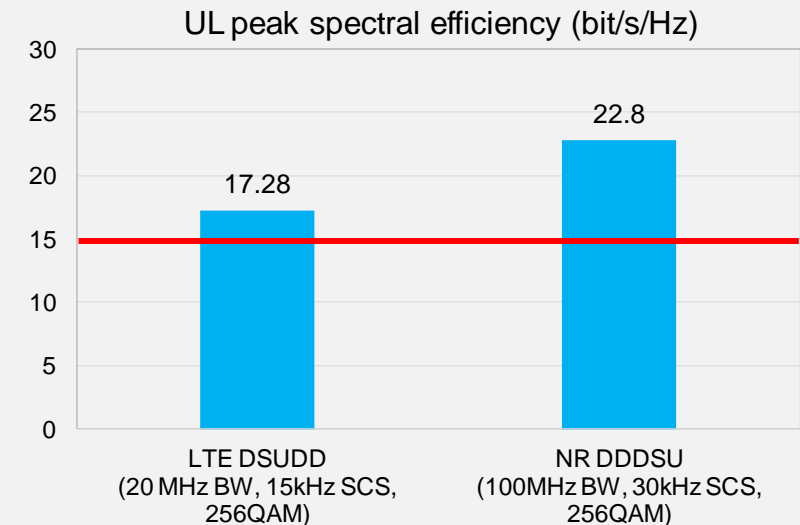
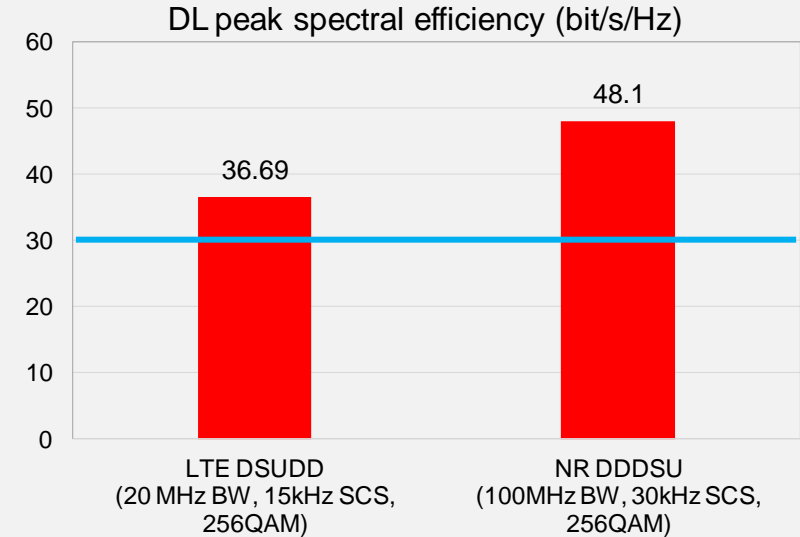
- **Peak spectral efficiency:**

- 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:**

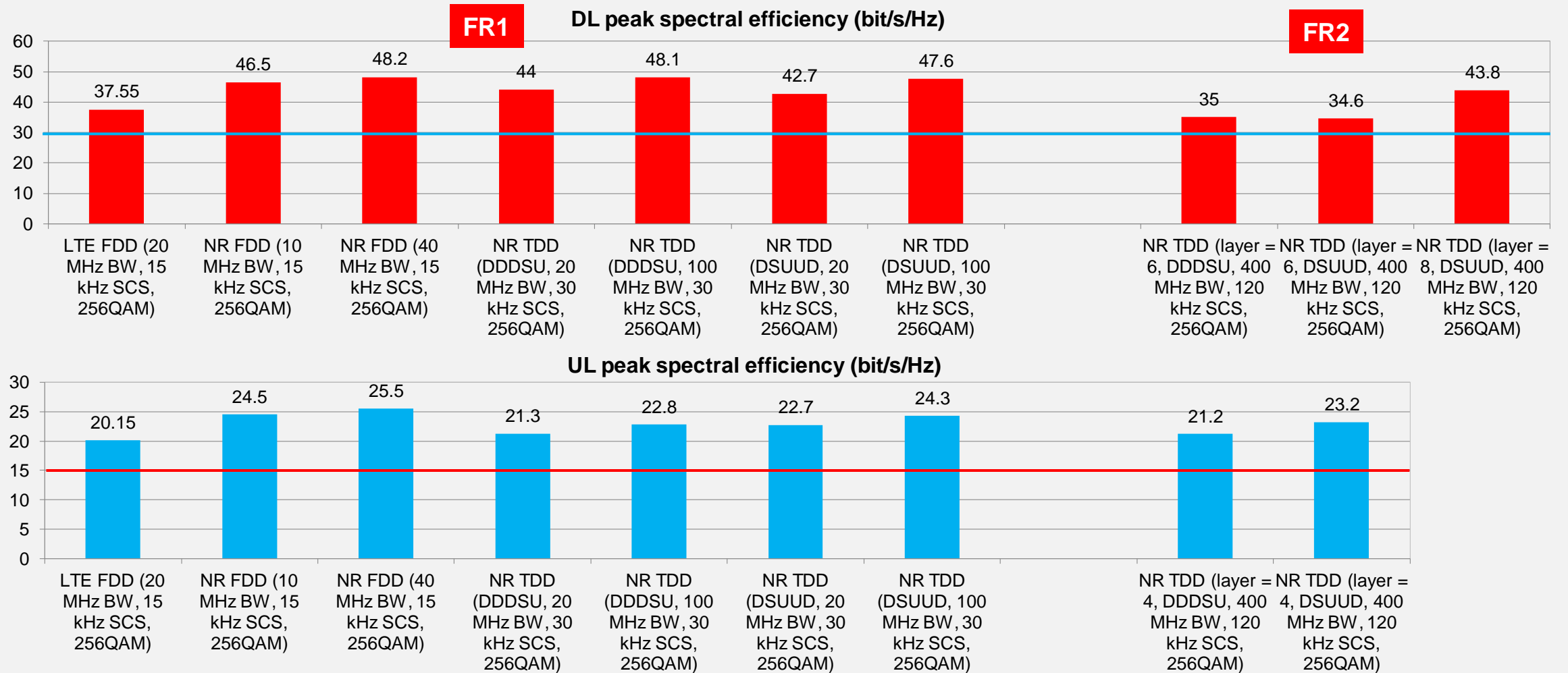
- NR large CC bandwidth introduces reduced guard band ratio
- NR small overhead for DL:
 - ✓ For PDCCH, as low as 0.6% @ 100 MHz for low load; 8-layer DMRS overhead reduced to 9.5%; no CRS
- NR small overhead for UL:
 - ✓ 4-layer DMRS overhead reduced to 7% under UL OFDMA; "Special subframe" can be used 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.

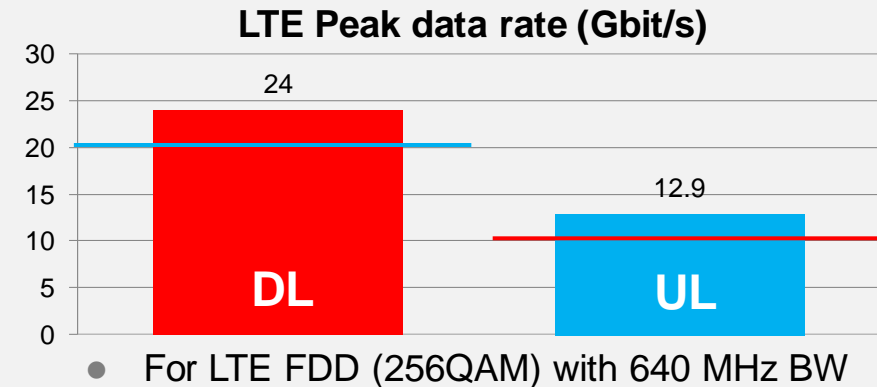
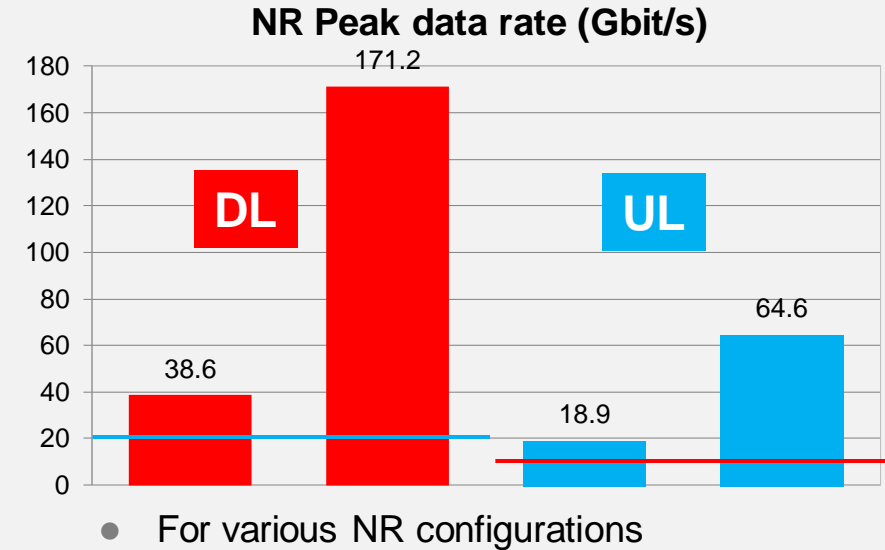


Preliminary evaluation on Peak data rate and spectral efficiency

- **Peak data rate:**

$$\text{Peak data rate} = (\text{Peak SE}) \times (\text{Aggregated bandwidth})$$

- 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**



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
-

2 OS for 10MHz

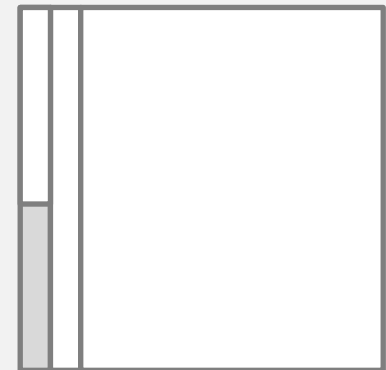


- NR PDCCH overhead reduction for large bandwidth

1 OS for 20MHz



0.5 OS for 40MHz

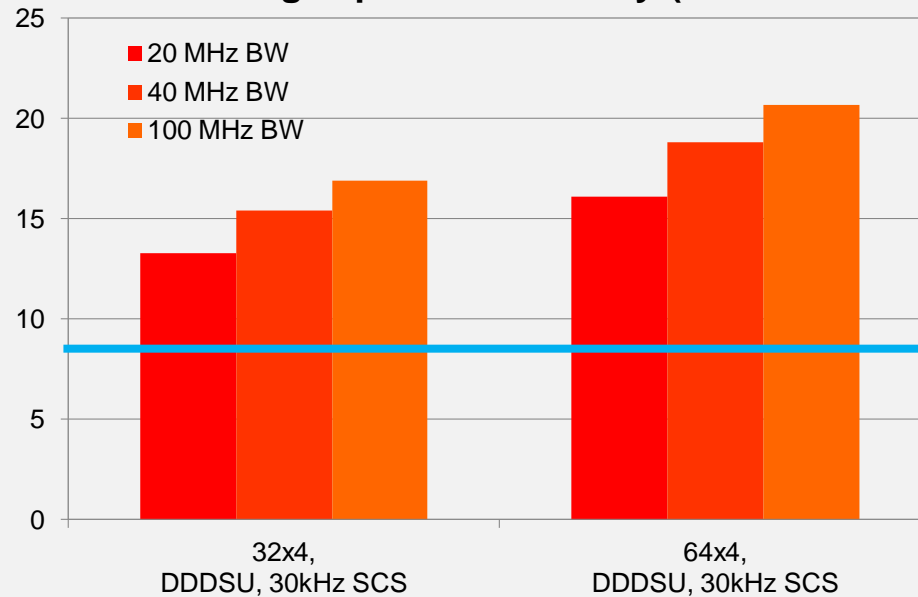


Preliminary evaluation on Average and 5th percentile user SE

- **Preliminary NR evaluation results for Dense Urban:**

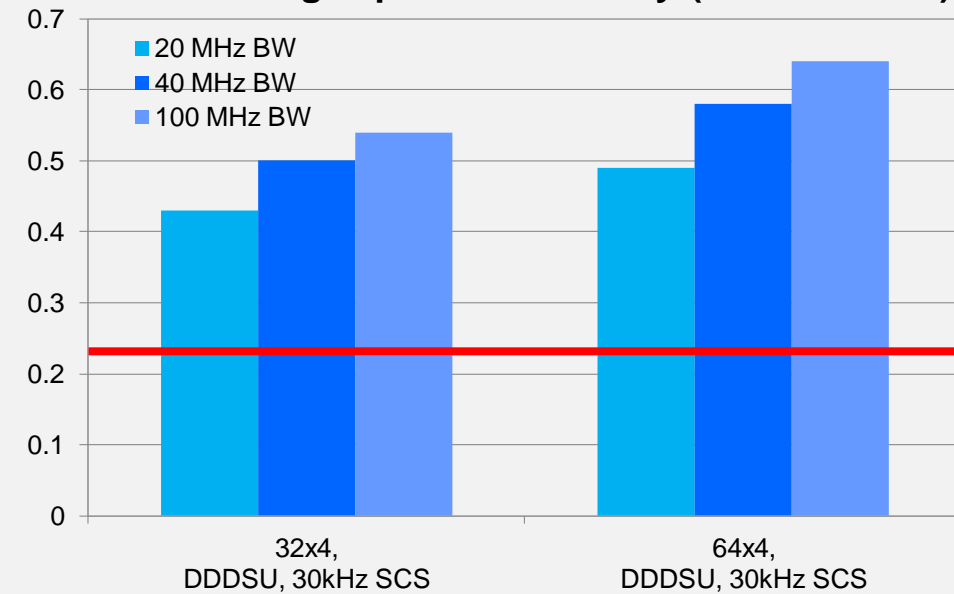
- Larger CC bandwidth brings improved SE (~30%) due to guard band ratio reduction and PDCCH overhead reduction
- NR Massive MIMO: 64 TXRU brings additional gain over 32 TXRU in TDD.

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



Dense Urban (4 GHz)

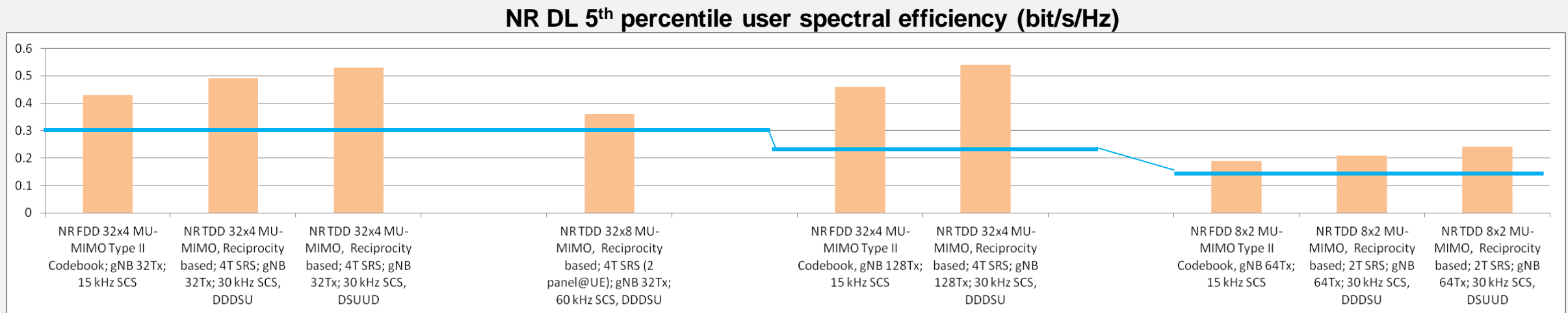
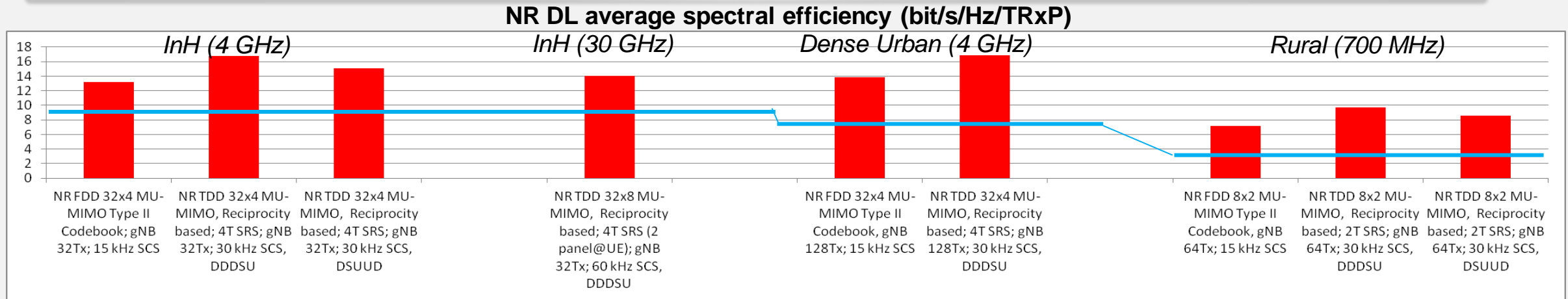
NR UL average spectral efficiency (bit/s/Hz/TRxP)



Dense Urban (4 GHz)

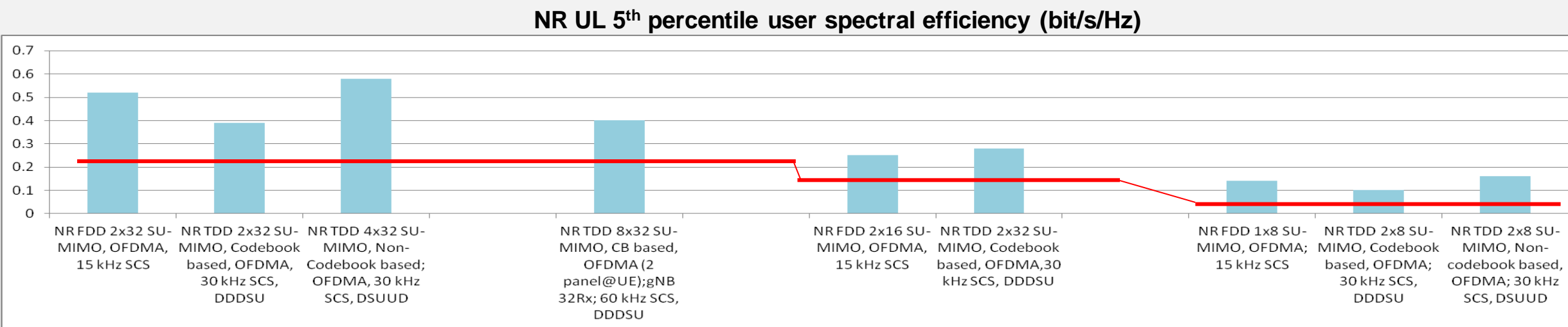
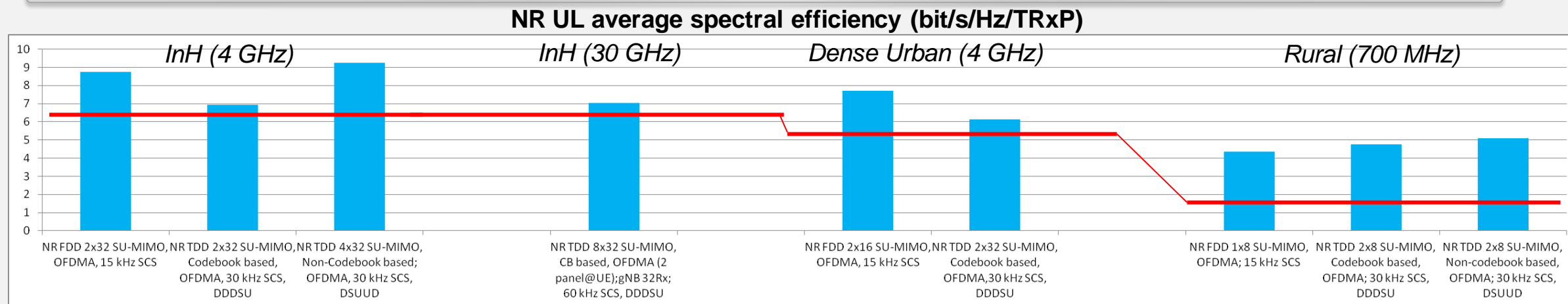
Preliminary evaluation on Average and 5th percentile user SE

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



Preliminary evaluation on Average and 5th percentile user SE

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

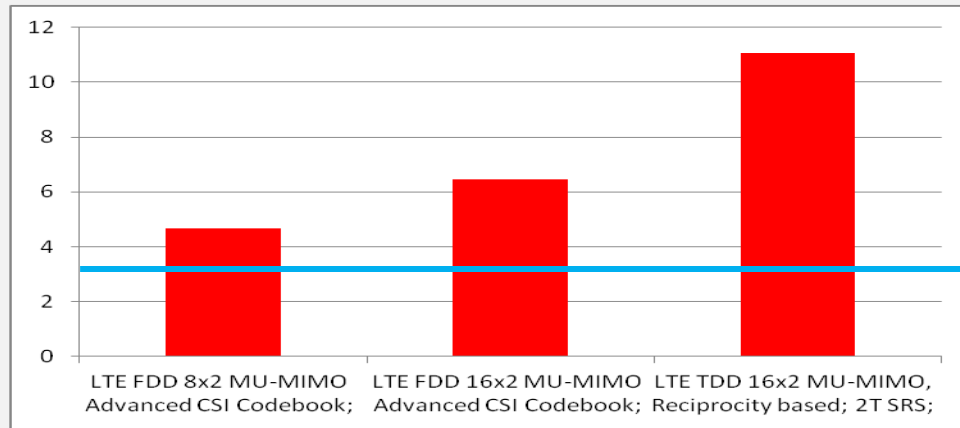


Preliminary evaluation on Average and 5th percentile user SE

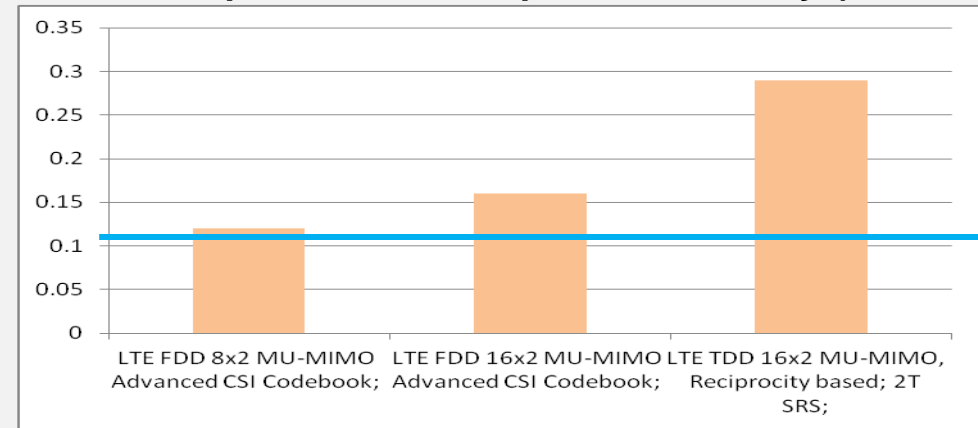
- Various LTE configurations are evaluated for Rural. See Section 5.4 of TR37.910 for details

DL

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

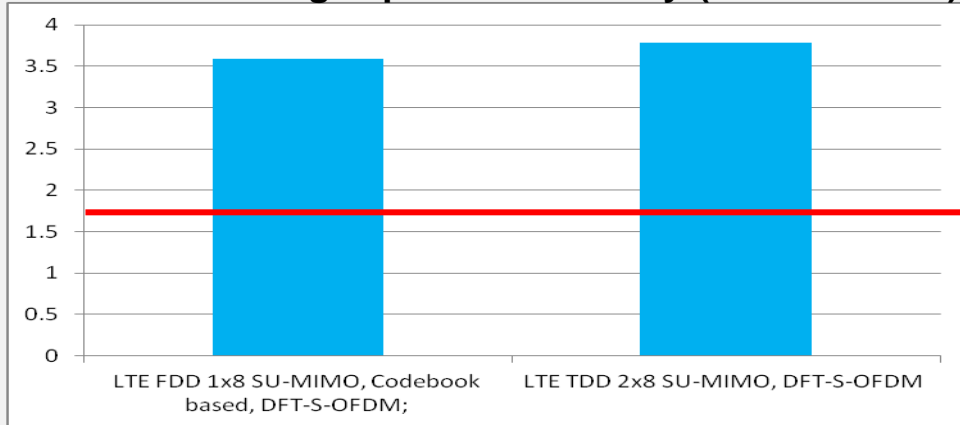


LTE DL 5th percentile user spectral efficiency (bit/s/Hz)

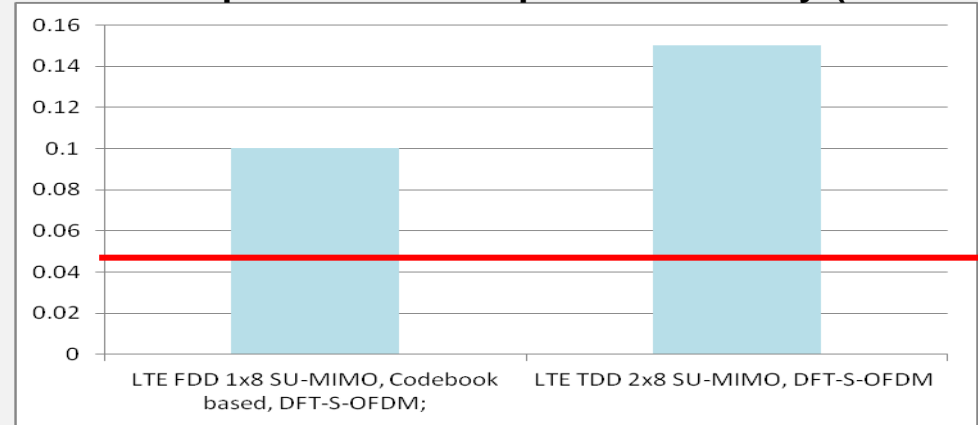


UL

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 (NR 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:**

$$\text{Area traffic capacity} = \frac{(\text{Average SE}) \times (\text{Aggregated bandwidth})}{(\text{Simulation area})}$$

- 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)

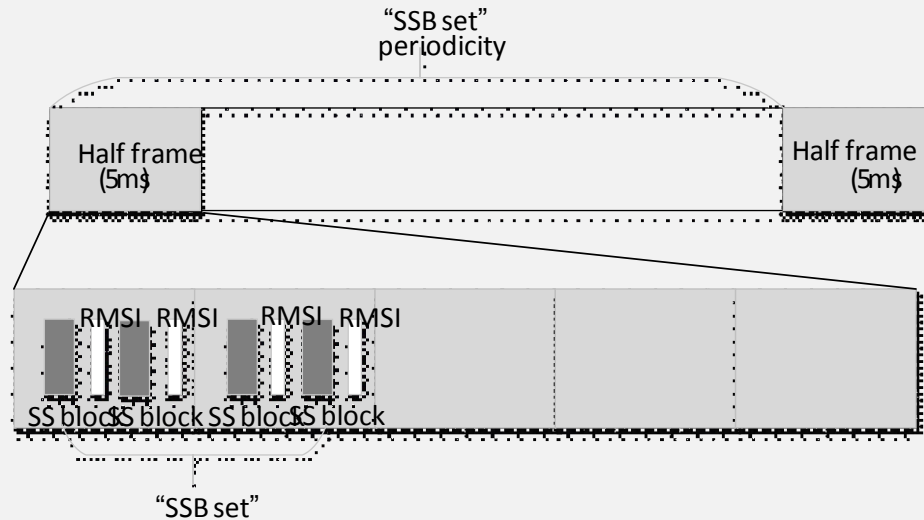
Frequency band	Required BW for DL target of 10 Mbit/s/m ²	
	12TRxP	36TRxP
4 GHz	360 MHz ~ 600 MHz	120 MHz ~ 280 MHz
30 GHz	400 MHz ~ 800 MHz	200 MHz ~ 400 MHz

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

Preliminary evaluation on Energy efficiency

– 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} 160ms
SCS [kHz]	Number of SS/PBCH block per SSB set, L	
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)

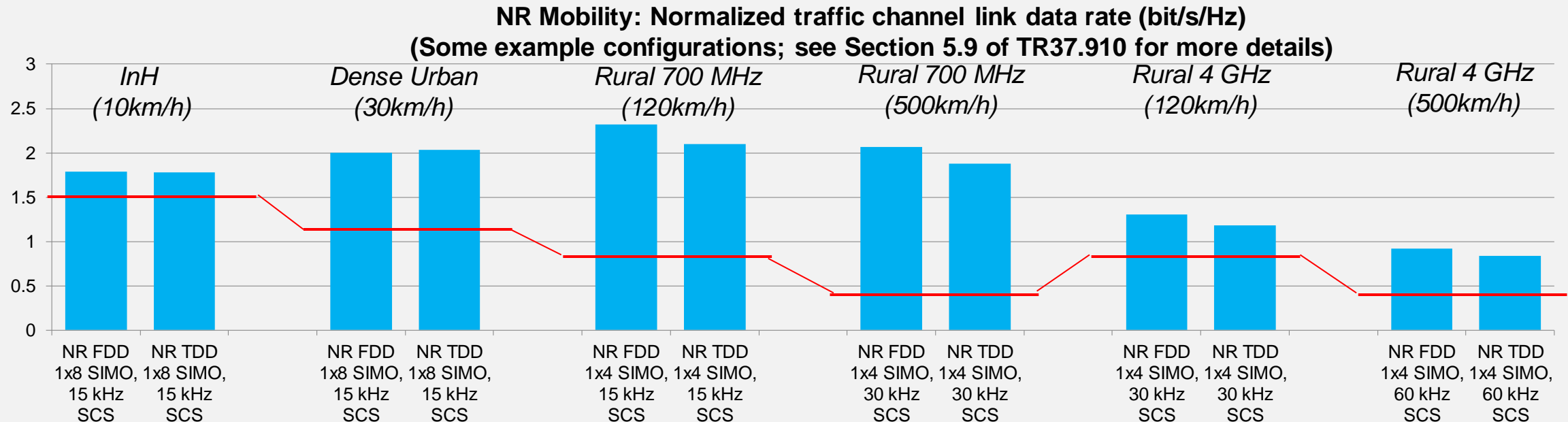
LTE Device sleep ratio under idle mode

	Paging cycle $N_{PC_RF} * 10$ (ms)	Synchronization reception time per cycle(ms)	Synchroniza tion 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.



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:*

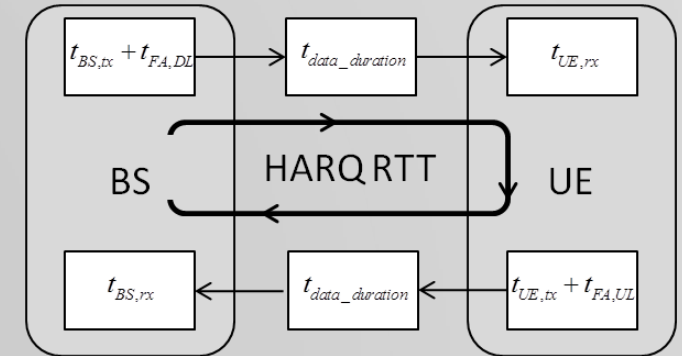
- ✓ SUL provided continuous uplink transmission opportunity to reduce DL ACK feedback and UL waiting time.
- ✓ This is especially useful for synchronized network with DL dominant configurations (e.g., DDDSU).

-

- **Contributing technical components for LTE:**

- *Short TTI*

-

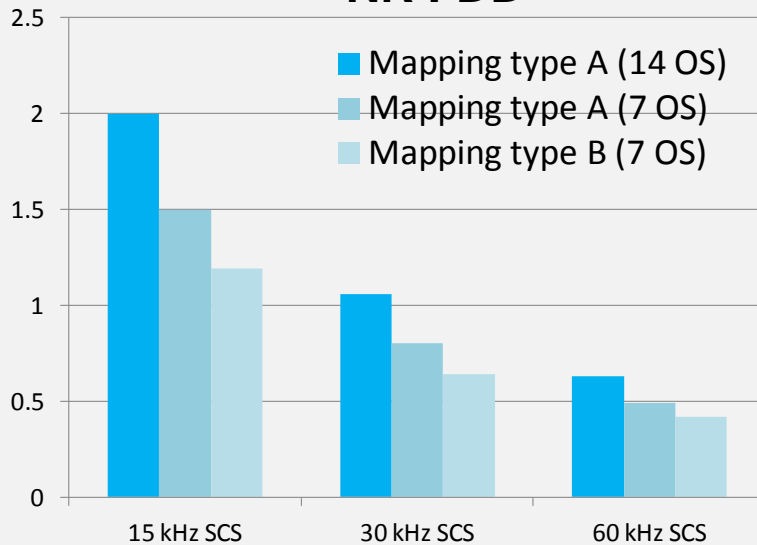


Preliminary evaluation on User plane latency

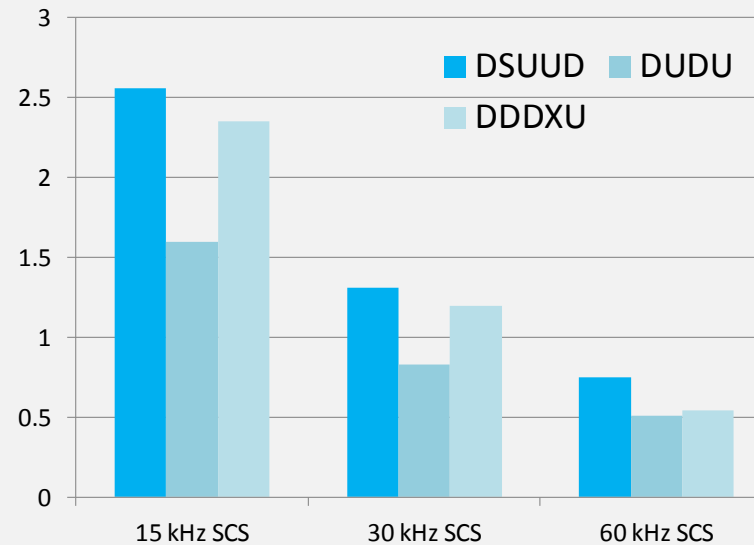
- Various configurations are evaluated for NR. See Section 5.7 of TR37.910 for more details.

UL UP latency for NR

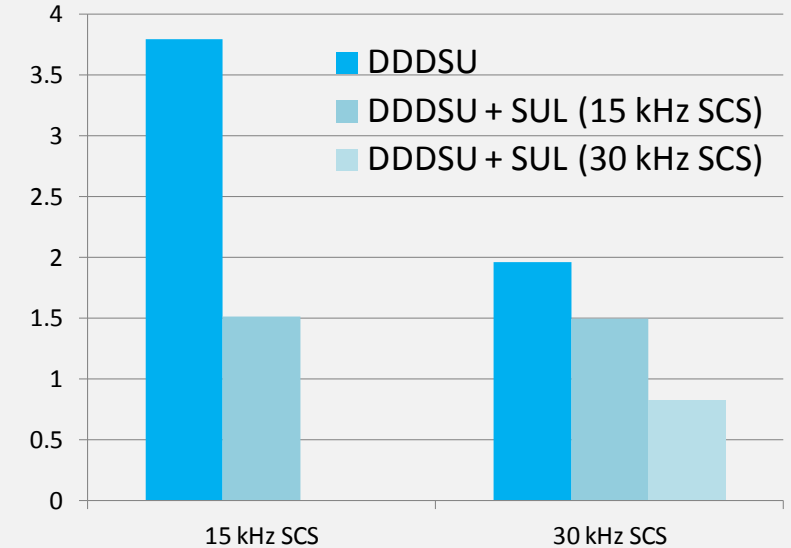
NR FDD



NR TDD*



NR TDD w/ SUL**



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

* Mapping type B (7 OS)

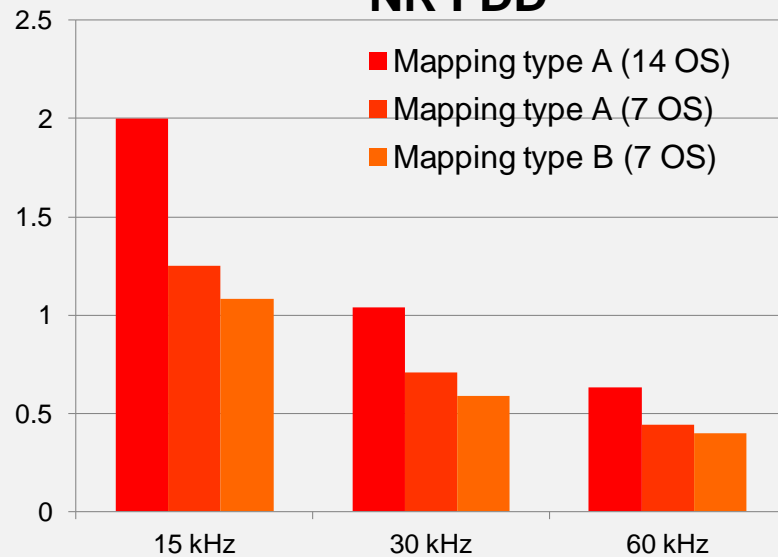
** Mapping type A (7 OS)

Preliminary evaluation on User plane latency

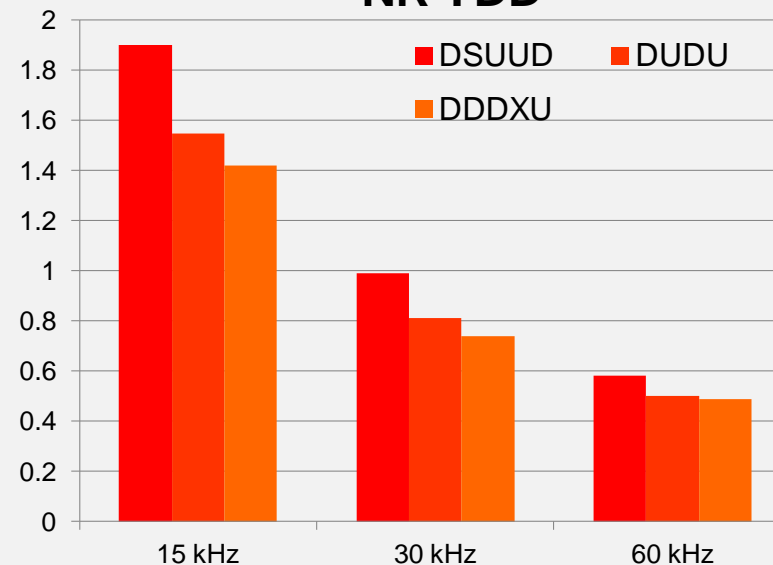
- Various configurations are evaluated for NR. See Section 5.7 of TR37.910 for more details.

DL UP latency for NR

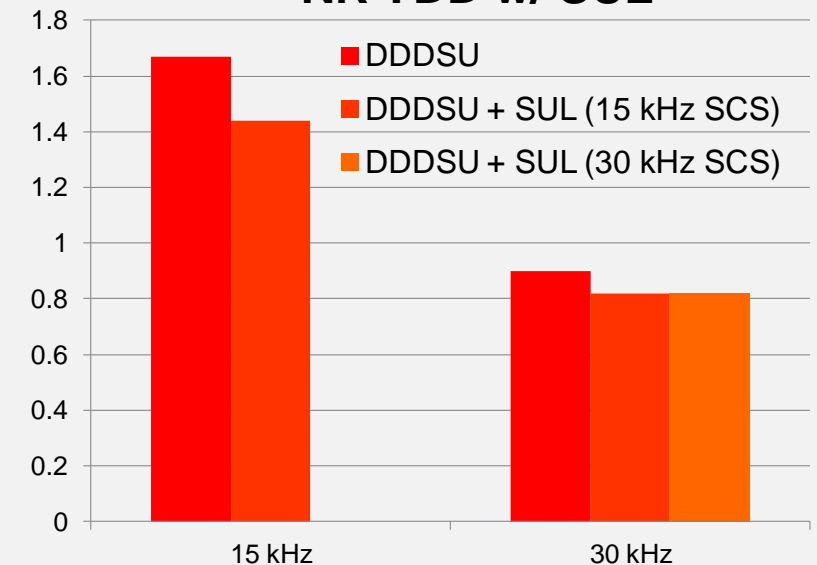
NR FDD



NR TDD*



NR TDD w/ SUL**



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

* Mapping type B (7 OS)

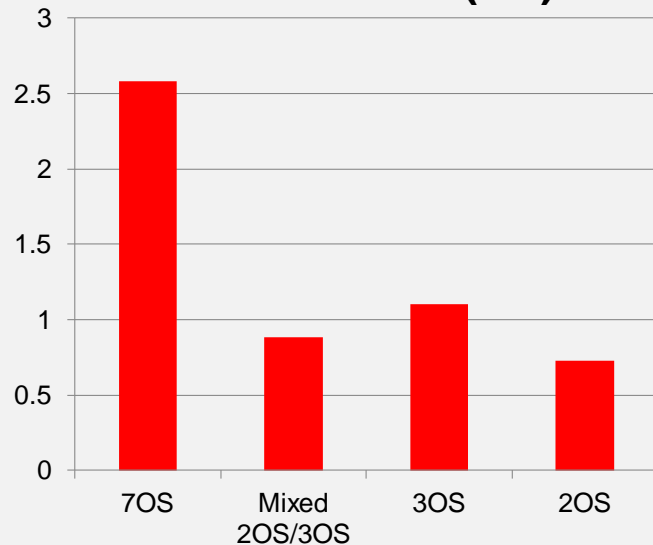
** Mapping type A (7 OS)

Preliminary evaluation on User plane latency

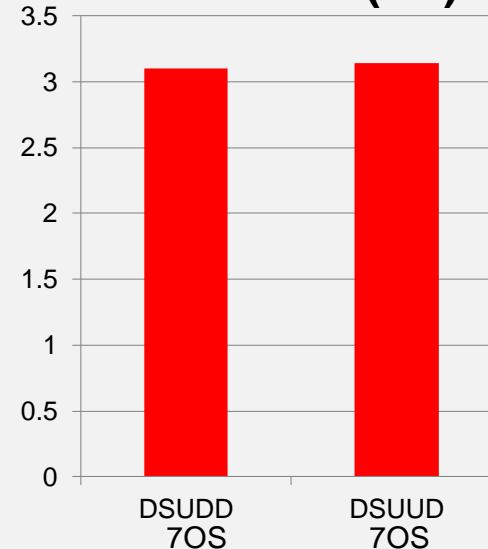
- Various configurations are evaluated for LTE. See Section 5.7 of TR37.910 for more details.

UP latency for LTE

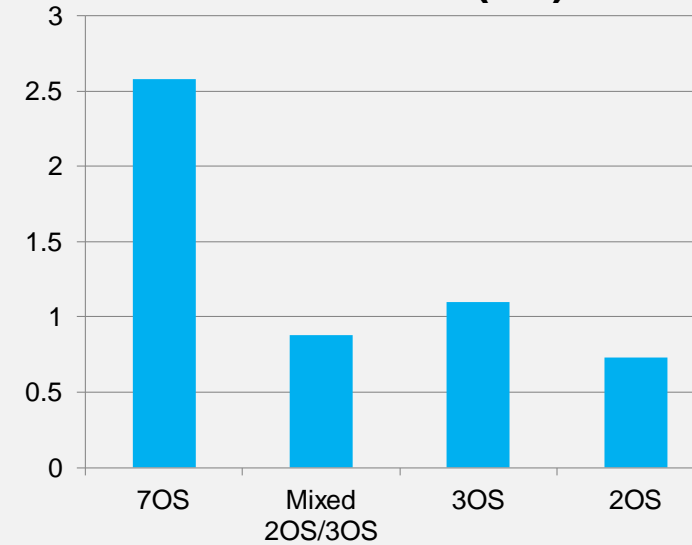
LTE FDD (DL)



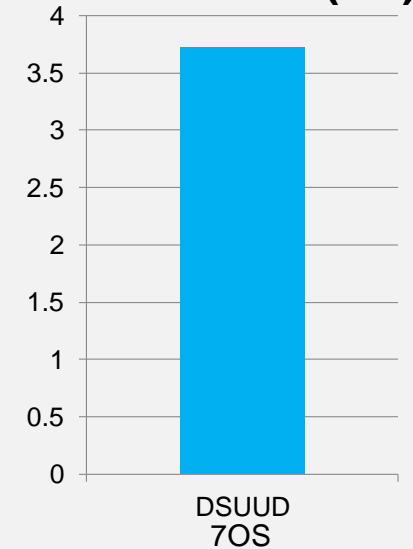
LTE TDD (DL)



LTE FDD (UL)



LTE TDD (UL)



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

Preliminary evaluation on Control plane latency

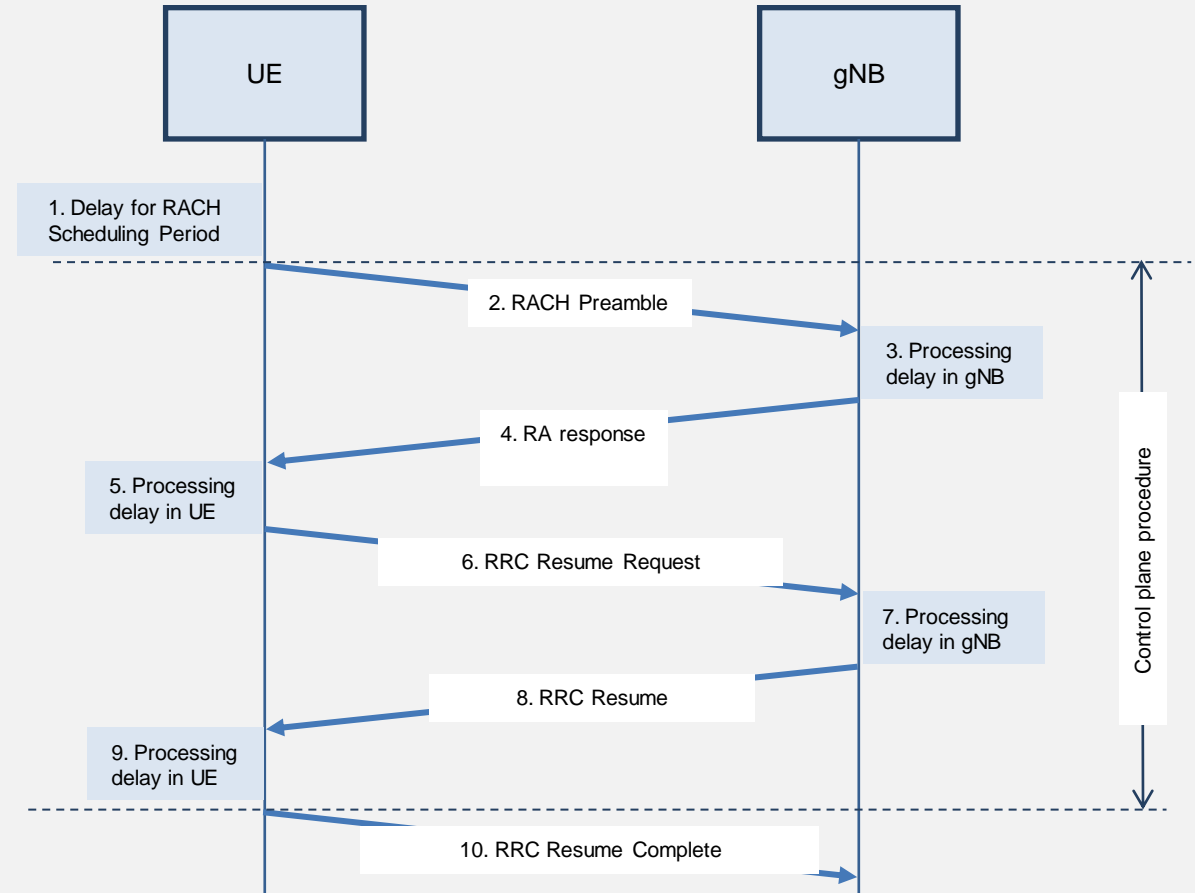
- Contributing technical components for NR include the use of RRC_INACTIVE state, as well as other components similar to UP latency.
- For LTE, the control plane latency is improved compared to Rel-10 by the use of RRC connection resume procedure, as well as by recognizing that some processing delay 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	
	5 th 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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3GPP RAN Workshop on 3GPP submission towards IMT-2020
October 24.-25. 2018, Brussels, Belgium

RWS-180019

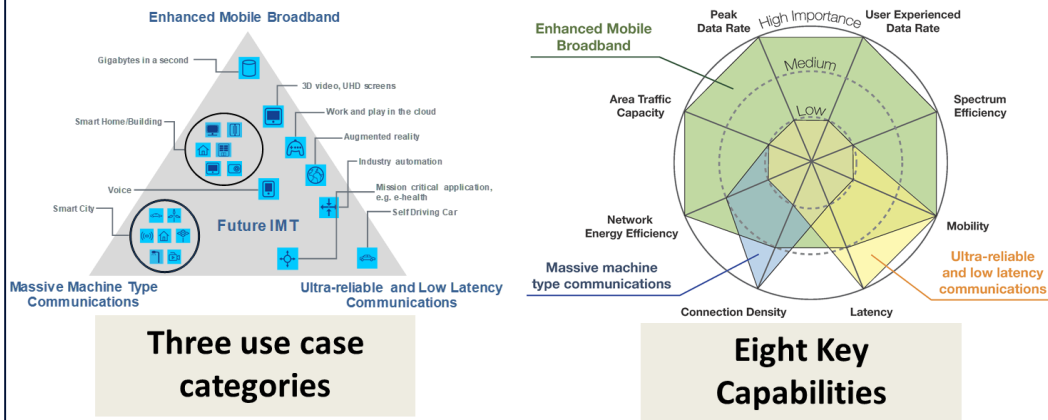
Self-Evaluation: URLLC and mMTC evaluation results

Source: Nokia

Categorization of IMT-2020 requirements

Source: 3GPP RWS-150036

ITU-R vision for IMT-2020 and beyond



“Framework and overall objectives of the future development of IMT for 2020 and beyond”

Source: ITU-R M.[IMT.VISION]

3GPP RAN workshop, 17.-18. September 2015

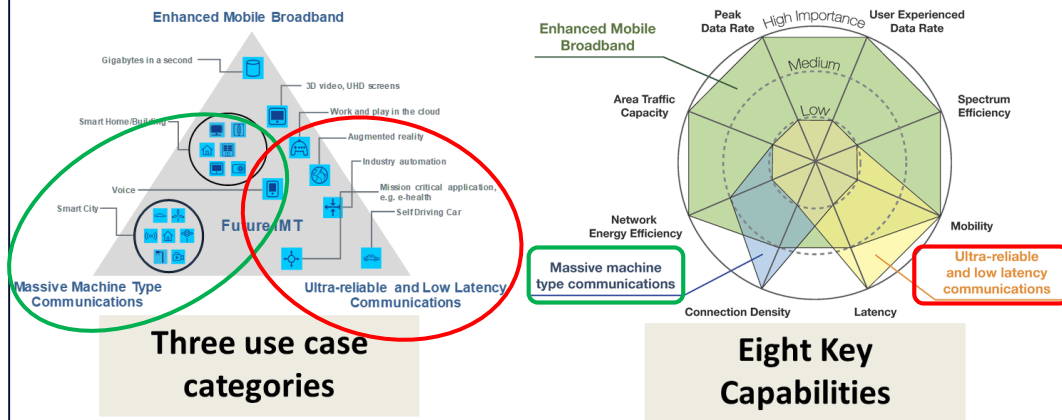
Source: ITU-R Report M.2410-0

- Peak data rate
- Peak spectral efficiency
- User experienced data rate
- 5th percentile user spectral efficiency
- Average spectral efficiency
- Area traffic capacity
- Latency
 - User plane latency
 - Control plane latency
- Connection density
- Energy efficiency
- Reliability
- Mobility
- Mobility interruption time
- Bandwidth

Categorization of IMT-2020 requirements – URLLC and mMTC

Source: 3GPP RWS-150036

ITU-R vision for IMT-2020 and beyond



“Framework and overall objectives of the future development of IMT for 2020 and beyond”

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3GPP RAN workshop, 17.-18. September 2015

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- Peak data rate
- Peak spectral efficiency
- User experienced data rate
- 5th percentile user spectral efficiency
- Average spectral efficiency
- Area traffic capacity
- **Latency**
 - User plane latency
 - Control plane latency
- **Connection density**
- Energy efficiency
- **Reliability**
- Mobility
- **Mobility interruption time**
- Bandwidth

Requirements for URLLC and mMTC

- Peak data rate
- Peak spectral efficiency
- User experienced data rate
- 5th percentile user spectral efficiency
- Average spectral efficiency
- Area traffic capacity
- **Latency**
 - User plane latency
 - Control plane latency
- **Connection density**
- Energy efficiency
- **Reliability**
- Mobility
- **Mobility interruption time**
- Bandwidth

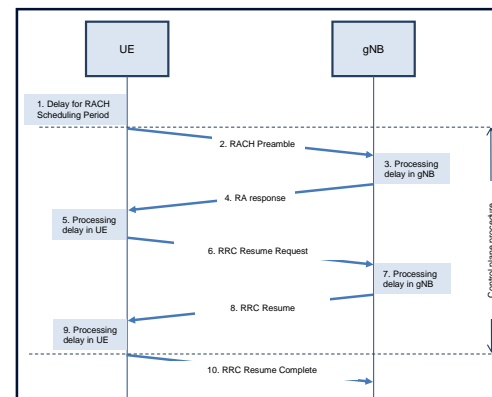
Requirement	Required value
Latency, user plane	1 ms for URLLC
Latency, control plane	20 ms
Connection density	1 000 000 devices / km ²
Reliability	99.999% success rate within 1 ms
Mobility interruption time	0 ms

URLLC requirement

mMTC requirement

Latency, control plane (URLLC)

*"Control plane latency refers to the transition time from a most "battery efficient" state (e.g. Idle state) to the start of continuous data transfer (e.g. Active state). [...] The minimum **requirement for control plane latency is 20 ms.** [M.2410-0]*



Number of configurations evaluated

	Evaluated	Passed
NR FDD	94	94
NR TDD	256	256
LTE FDD	1	1
LTE TDD	12	12

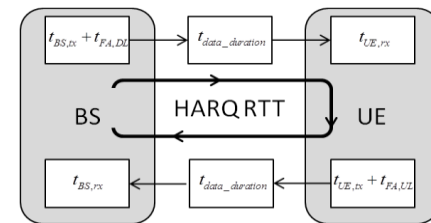
Example: 35 NR FDD configurations for 6-symbol PRACH (ms)

Control plane latency NR FDD		UE capability 1				UE capability 2		
		Subcarrier spacing				Subcarrier spacing		
Allocation		15 kHz	30 kHz	60 kHz	120 kHz	15 kHz	30 kHz	60 kHz
Mapping Type A	4 symbols	15.6	13.5	12.4	11.7	15.1	13.0	12.1
	7 symbols	15.8	13.6	12.5	11.7	15.3	13.1	12.2
Mapping Type B	2 symbols	13.7	12.3	11.9	11.4	13.4	12.0	11.7
	4 symbols	14.2	12.5	12.0	11.5	13.9	12.3	11.8
	7 symbols	15.3	13.0	12.3	11.6	14.8	12.8	12.1

Requirement of 20 ms control plane latency is met with all evaluated configurations

Latency, user plane (URLLC)

*"User plane latency is the contribution of the radio network to the time from when the source sends a packet to when the destination receives it (in ms).
[...] The minimum requirements for user plane latency are [...] 1 ms for URLLC. [M.2410-0]"*



Number of configurations evaluated

	Downlink		Uplink	
	Evaluated	Passed	Evaluated	Passed
NR FDD	84	64	98	67
NR TDD	368	225	370	148
LTE FDD	8	5	8	5
LTE TDD	8	0	6	0

Example: 84 NR FDD DL configurations (ms)

DL user plane latency NR FDD			UE capability 1				UE capability 2		
			Subcarrier spacing				Subcarrier spacing		
Allocation		Re-Tx	15 kHz	30 kHz	60 kHz	120 kHz	15 kHz	30 kHz	60 kHz
Mapping Type A	4 symbols	p=0	1.37	0.76	0.54	0.34	1.00	0.55	0.36
		p=0.1	1.58	0.87	0.64	0.40	1.12	0.65	0.41
	7 symbols	p=0	1.49	0.82	0.57	0.36	1.12	0.61	0.39
		p=0.1	1.70	0.93	0.67	0.42	1.25	0.71	0.44
	14 symbols	p=0	2.13	1.14	0.72	0.44	1.80	0.94	0.56
		p=0.1	2.43	1.29	0.82	0.51	2.00	1.04	0.63
Mapping Type B	2 symbols	p=0	0.98	0.56	0.44	0.29	0.49	0.29	0.23
		p=0.1	1.16	0.67	0.52	0.35	0.60	0.35	0.28
	4 symbols	p=0	1.11	0.63	0.47	0.31	0.66	0.37	0.27
		p=0.1	1.30	0.74	0.56	0.36	0.78	0.45	0.32
	7 symbols	p=0	1.30	0.72	0.52	0.33	0.93	0.51	0.34
		p=0.1	1.49	0.83	0.61	0.39	1.08	0.59	0.40

Requirement of 1 ms user plane latency is met with a number of different configurations

Reliability (URLLC)

*"Reliability relates to the capability of transmitting a given amount of traffic within a predetermined time duration with high success probability. [...] The minimum **requirement for the reliability is 1-10⁻⁵ success probability** [...] within 1 ms in channel quality of coverage edge... [M.2410-0]*

*"It is sufficient to fulfil the requirement in either downlink or uplink, using either NLOS or LOS channel conditions."
[M.2412-0]*

Number of configurations evaluated

	Downlink		Uplink	
	Evaluated	Passed	Evaluated	Passed
NR FDD	16	16	26	26
NR TDD	-	-	1	1
LTE FDD	-	-	-	-
LTETDD	-	-	-	-

Example: 9 NR FDD DL configurations at 4 GHz (ms)

Antenna configuration	Allocation	Sub-carrier spacing	Channel	Channel model A	Channel model B
2x2 SU-MIMO	14 symbols, slot aggregation	60 kHz	NLOS	99.999899%	99.99991%
2x2 SU-MIMO	4 symbols, HARQ re-tx	30 kHz	NLOS	99.999898%	99.99995%
2x2 SU-MIMO	4 symbols, one shot	30 kHz	NLOS	99.99971%	99.99969%
2x4 SU-MIMO	7 symbols, one shot	30 kHz	NLOS	>99.9999%	>99.9999%
32x8 SU-MIMO	14 symbols, one shot	30 kHz	NLOS	99.9999%	-

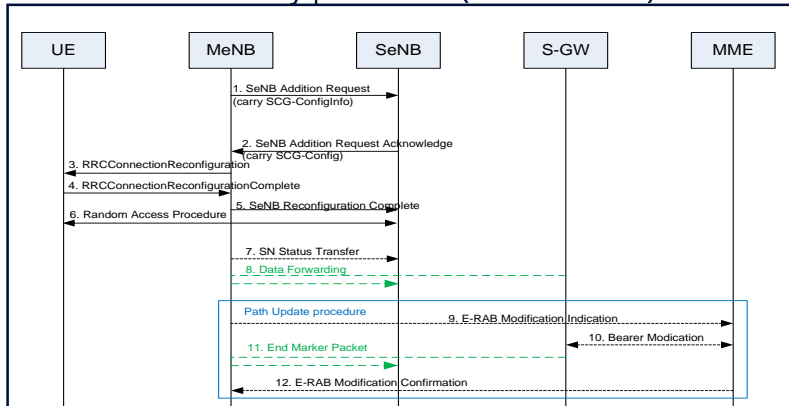
Requirement of 99.999% reliability within 1 ms packet delivery is met in all evaluated configurations

Mobility interruption time (URLLC)

*"Mobility interruption time is the shortest time duration supported by the system during which a user terminal cannot exchange user plane packets with any base station during transitions.[...]The minimum **requirement for mobility interruption time is 0 ms.**" [M.2410-0]*

"The procedure of exchanging user plane packets with base stations during transitions shall be described based on the proposed technology including the functions and the timing involved." [M.2412-0]

DC mobility procedure (Scell addition)



Technical feature

Meets requirement

NR beam mobility

Yes

NR CA mobility

Yes

LTE Pcell mobility

Yes

LTE DC mobility

Yes

Requirement of zero ms mobility interruption time is met

Connection density (mMTC)

"Connection density is the total number of devices fulfilling a specific quality of service (QoS) per unit area (per km²). [...] The minimum requirement for connection density is **1 000 000 devices per km²**. " [M.2410-0]

"The requirement is fulfilled if the 99th percentile of the delay per user D_i is less than or equal to 10s, and the connection density is greater than or equal to the connection density requirement... " [M.2412-0]

Connection density evaluation results (full buffer method)

Technical feature	ISD (m)	Scheme and antenna config.	Sub-carrier spacing	Channel model A		Channel model B	
				Connection density (device/km ²)	Required bandwidth (kHz)	Connection density (device/km ²)	Required bandwidth (kHz)
NR	500	1x2 SIMO OFDMA	15 kHz	35,569,150	180	35,082,937	180
	1732			1,267,406		1,529,707	
NB-IoT	500	1x2 SIMO	15 kHz	43,691,789	180	43,626,653	180
	1732			2,335,319		2,376,936	
eMTC	500	1x2 SIMO	15 kHz	35,235,516	180	34,884,438	180
	1732			1,212,909		1,511,989	

Requirement of 1 000 000 devices/km² is met in all evaluated cases

Large number of different configurations evaluated against the URLLC and mMTC requirements

Requirement	Required value	NR	LTE
Latency, user plane	1 ms for URLLC	Meets requirement	Meets requirement
Latency, control plane	20 ms	Meets requirement	Meets requirement
Connection density	1 000 000 devices / km ²	Meets requirement	Meets requirement
Reliability	99.999% success rate within 1 ms	Meets requirement	Not evaluated
Mobility interruption time	0 ms	Meets requirement	Meets requirement

3GPP successfully completed the preliminary self evaluation on URLLC and mMTC

A close-up photograph of a person's hand adjusting a black knob on a light-colored control panel. The panel features several other controls, including a switch labeled 'AUTO', two analog gauges, and a switch labeled 'TIME DIFFERENCE UNIT'. The background is blurred, showing more of the control panel. The word 'NOKIA' is overlaid in white, bold, sans-serif capital letters in the center of the image.

NOKIA



RAN outlook – Rel16 and beyond

Balazs Bertenyi (Chairman of 3GPP RAN)

Outline



- 5G vision driving the evolutionary path
- 5G evolution: Expansion and Efficiency

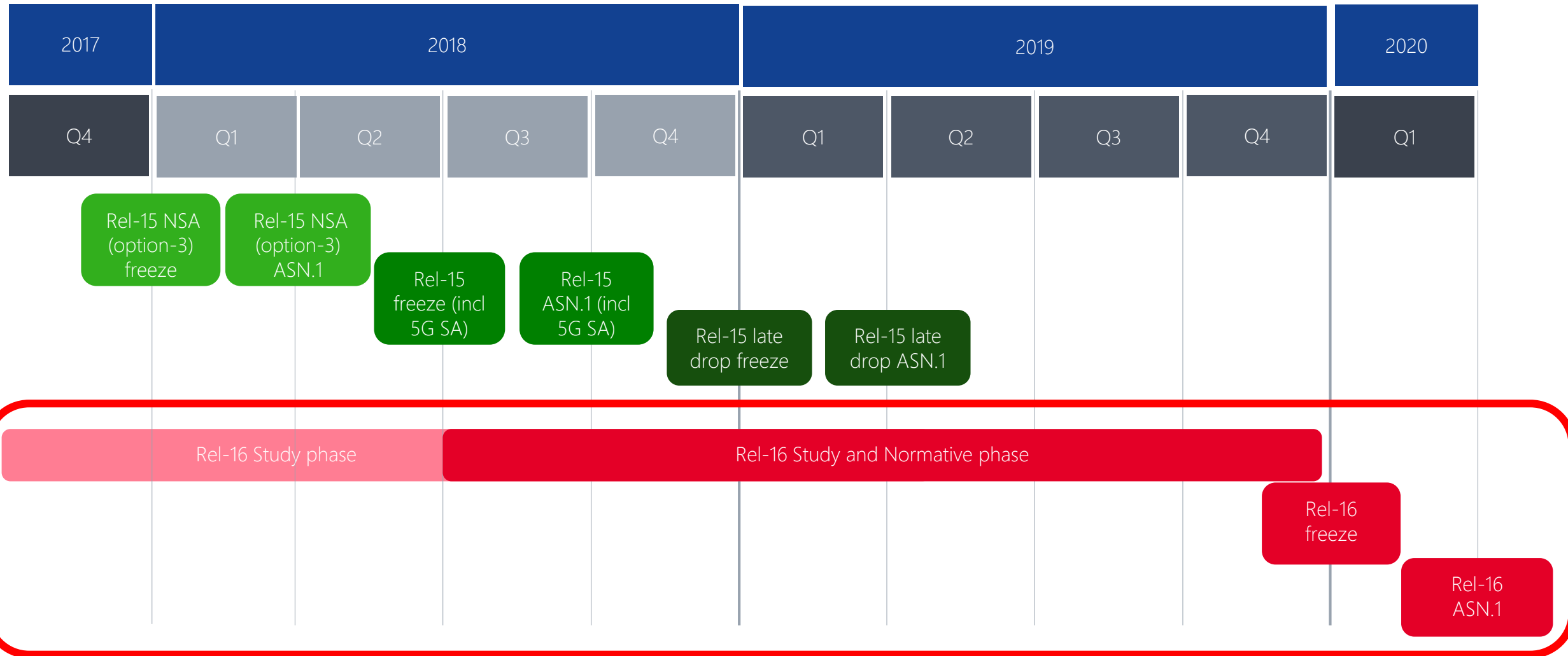
5G vision - for real



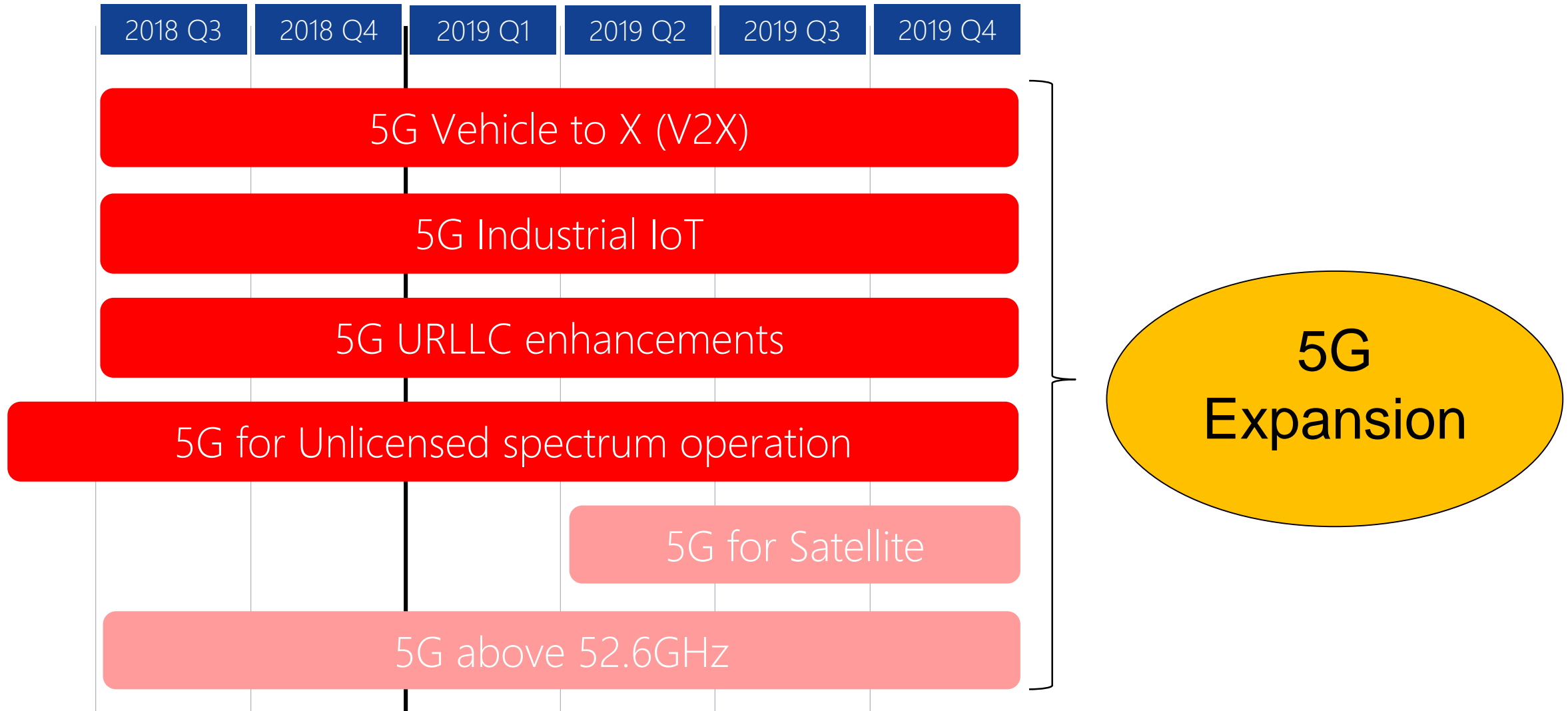
Perfect storm of multiple technology breakthroughs:

- **Low latency** radio with fully flexible network
- **Artificial Intelligence** and Automation
- **Device revolution** for AR/VR
- **Vertical industries** going cellular

Timeline



Release 16 – 5G Expansion



V2X evolution towards 5G



Evolution to 5G,
while maintaining backward compatibility

Basic safety
802.11p or C-V2X R14

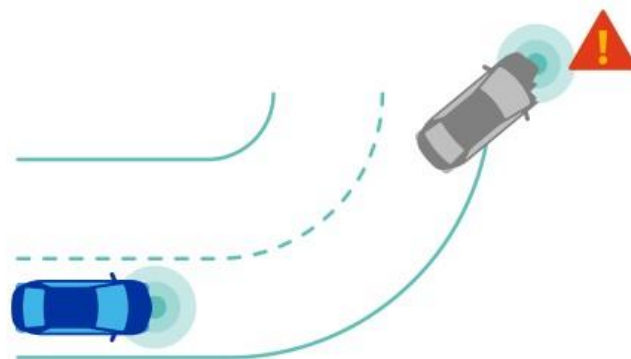
Established foundation
for V2X



Basic Safety services
incl. warnings and signal
phase information

Enhanced safety
C-V2X R14/15

Enhanced range and reliability



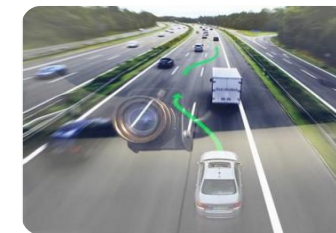
Advanced safety
C-V2X R16 (building upon R14)

Higher throughput
Higher reliability

Wideband ranging
and positioning
Lower latency



Vehicle
Platooning



Cooperative Manoeuvre,
Sensor sharing



Remote Driving



Advanced Driving

Industrial IoT and URLLC



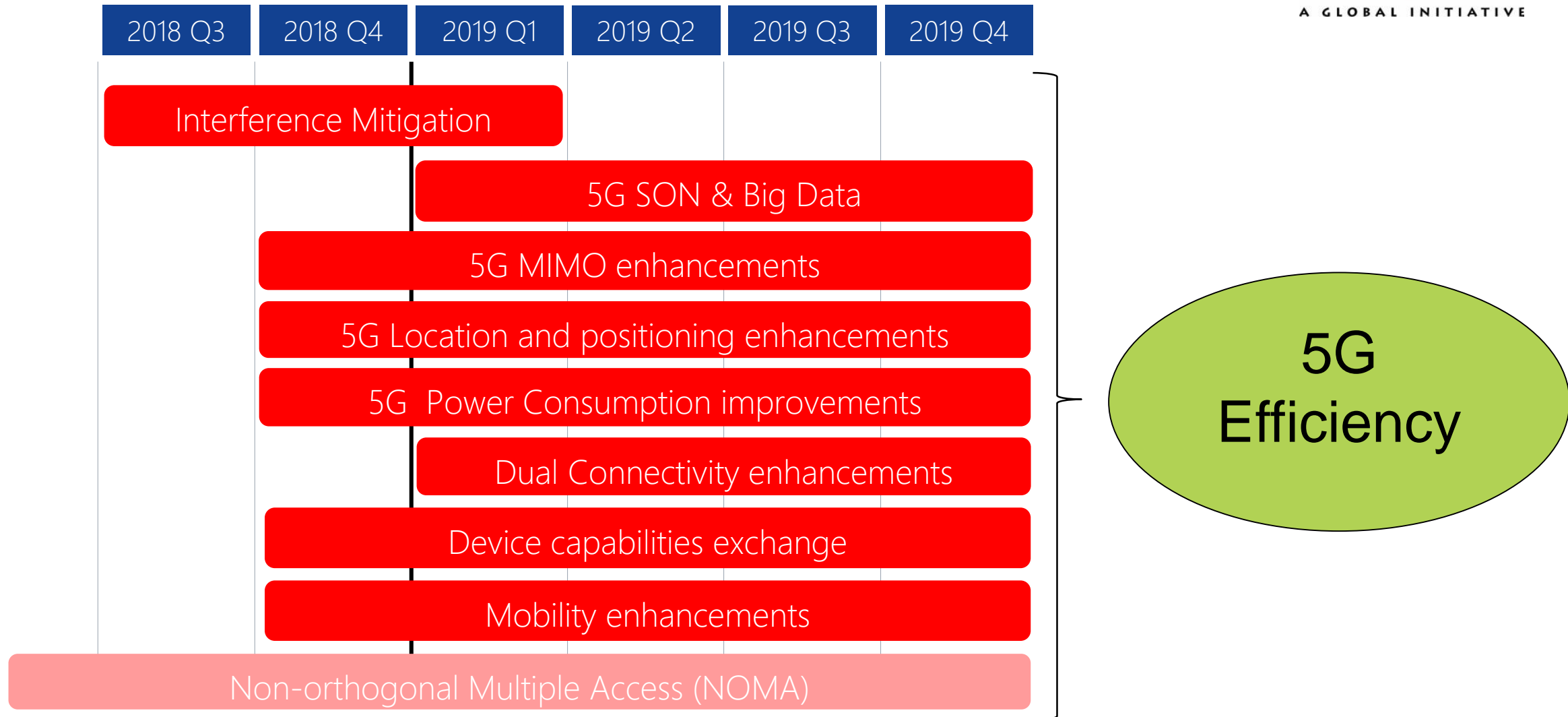
- Focus on both commercial and industry use
 - AR/VR, Factory automation, Transport Industry (incl Automotive), Electrical Power Distribution
- Establishing Rel15 baseline performance
- Time Sensitive Networking (TSN)
 - Accurate reference timing, wireless Ethernet, etc...
- Reliability and latency enhancements: L1/L2/L3 concepts
- Intra-UE prioritization and multiplexing

5G NR in unlicensed bands



- 3GPP work on unlicensed operation will be focused on NR
 - No new functions on LTE-LAA
- NR-U specifications kept separate, not part of the ITU submission
- Focus is on bands below 7GHz
- Addresses both LAA and Standalone operation
- Co-existence with LTE-LAA and other incumbent technologies

Release 16 – 5G Efficiency

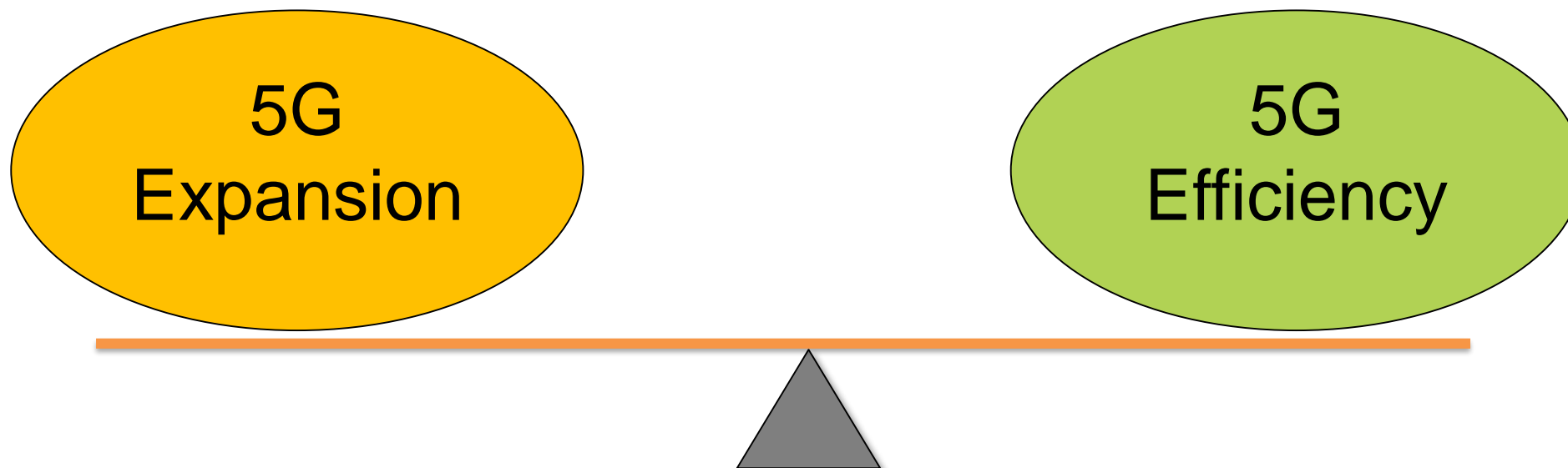


Positioning in 5G



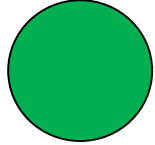
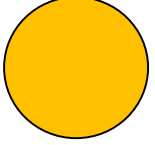
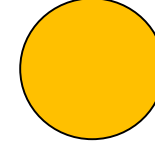
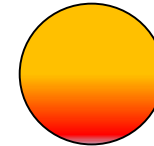
- Going beyond basic regulatory requirements (E911)
- Start with identifying accuracy, latency, capacity and coverage requirements
- Both commercial and regulatory scenarios
- Both indoor and outdoor
- Both low (FR1) and high (FR2) frequency bands

Balance



5G vision – where are we?

Perfect storm of multiple technology breakthroughs:

- **Low latency** radio with fully flexible network 
- **Artificial Intelligence** and Automation 
- **Device revolution** for AR/VR 
- **Vertical industries** going cellular 

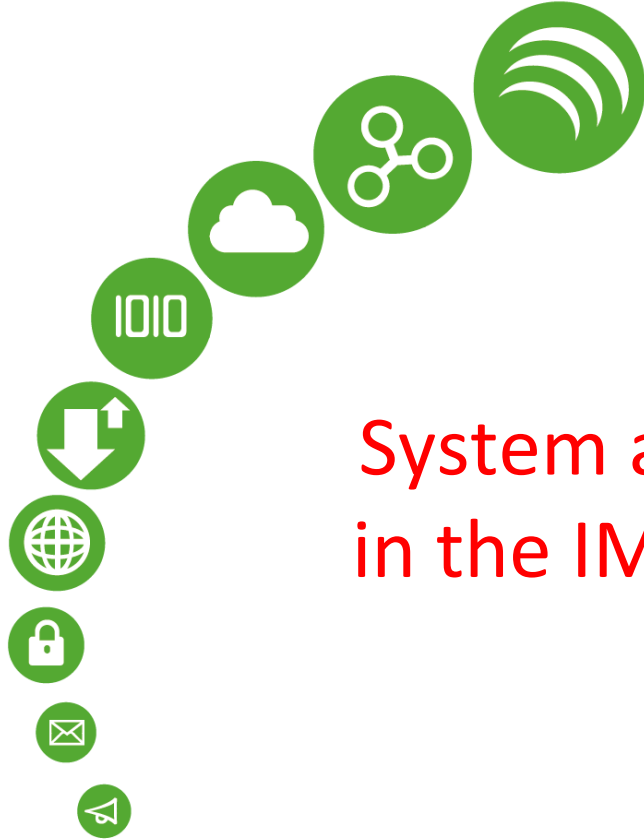


Thank you!



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System and Service aspects in the IMT-2020 submission

IMT-2020 Submission Non-Radio Aspects



- 📶 As in past IMT submissions, 3GPP will include an informative list of all non-RAN specifications.
 - It is important to emphasize that the 3GPP system is much more than the 3GPP radio aspects.
 - This list will include **fewer** specifications than in past submissions, as the 5G system explicitly does not support full backward compatibility with the 2G and 3G system (IMT-2000).

5G 3GPP Specifications



- 📶 5G specifications began in Release 15.
 - These specifications include not only the new 5G components, but also the continuing evolution of the 4G system.
- 📶 New 5G specifications have been introduced across 3GPP.
- 📶 Some 4G specifications are now 5G specifications, from Rel-15
 - The Enhanced Packet Core and other 4G standards are important components of 5G.
 - Operators will deploy and integrate 5G functionality in different ways, including continuing use of the EPC for some time.
 - **See TS 21.205 – which links to a list of 1113 specifications.**



System and Service aspects in Release 16

System and Core Network Aspects

- 📶 System and Core Network Aspects, as discussed in this presentation, include everything in scope of 3GPP standardization *except* Radio Access Network aspects.
- 📶 **System Aspects** include: Security, Media and Codecs, Operations and Management, Applications, Terminal and End to End Aspects, Interworking with External Networks and Smart Card Application Aspects
- 📶 **Core Network Aspects** include: all functions to support for services provided by the 3GPP system.
 - These categories are somewhat arbitrary. Some functions could be considered both Core Network and System Aspects.

Overview of System & CN Aspects (1/2)

Release 15 (5G Phase 1)

- 📶 Stage 1 – Service Requirements for 5G
 - TS 22.261 “New Services and Markets Technology Enablers”
- 📶 Stage 2 – 5G System defined in
 - TS 23.501 “System Architecture for the 5G System”
 - TS 23.502 “Procedures”
 - TS 23.503 “Policy and Charging Control Framework for the 5G System”
 - TS 33.501 “Security architecture and procedures for 5G System”

Release 16 (5G Phase 2)

- 📶 Stage 1 – Service Requirements for 5G
 - Adds requirements for **verticals** from Industrial & Vertical automation, 5G Satellite, LAN support, High Precision Positioning, QoS Monitoring. New specification TS 22.104 on Cyber-Physical Control Applications.
- 📶 Stage 2 – 5G System expands in
 - Adds support to the TSs for **verticals**: URLLC, 5G LAN, 5GC Location Services, Enhanced V2X, Cellular IoT
 - Adds support for **new accesses**: Wireless Wireline Convergence, Satellite, SRVCC from 5GS to 3G
 - **Enhancements to the base system**: Network Automation, Traffic Steering/Switch/Splitting, Service Based Architecture, Network Slicing, Radio Capabilities, User Data Interworking...

Overview of System & CN Aspects (2/2)

Release 15 (5G Phase 1)

Stage 2, continued

- Application : TS 23.222 “Common API Framework for 3GPP Northbound APIs”
- Media: TS 26.118 “3GPP Virtual reality profiles for streaming applications”
- Charging*: TS 32.291 “5G System Charging Service”
- OAM*: TS 28.530..554 “Management and orchestration”, many aspects
- OAM*: TS 28.304..306 “Control and Monitoring of Power, Energy and Environmental Parameters”

Release 16 (5G Phase 2)

Stage 2, continued

- 5G Support for **verticals**: Mission Critical support over 5G (Spec TBD), V2X Application support (Spec TBD)
- 5G support for **media**: coverage and handoff enhancements, QoE metrics for VR, 5G Mobile Broadband Media Distribution, V2X Media Handling, Extensions or 5G Conversational Services, Many enhancements, study on XR (Extended Reality) (Specs TBD)
- **OAM support** extends to: ONAP interworking for Configuration Management, Data Collection, Analytics and Events, Self-Organizing Networks, QoE measurement collection, slice management, energy efficiency, orchestration & virtualization....

3GPP Rel-16: Ongoing RAN-SA Studies



Common 5G focus areas across Radio Access Network and System / Core Network

Focus Area	System Studies	RAN Studies
URLLC for 5G	Enhancement of URLLC support in 5G, Enhanced support of Vertical and LAN Services, Cyber-physical control applications in vertical domains	Physical layer enhancements for NR UR Low Latency Cases, NR-based access to unlicensed spectrum, NR Industrial Internet of Things
V2X for 5G	Architecture enhancements for 3GPP support of advanced V2X services	NR Vehicle-to-Everything (V2X)
Positioning	Enhancement to the 5GC Location Services, 5G positioning services	NR positioning support
UE Capabilities	Optimisations on UE radio capability signalling	Optimisations on UE radio capability signalling – NR/E-UTRA Aspects
5G Satellite Aspects	Architecture aspects for using satellite access in 5G, Integration of Satellite Access in 5G	Solutions for NR to support non-terrestrial networks (NTN)

Many other features have *impacts* across the system (both in RAN and non-RAN areas), however, these are mainly handled on one side or the other. They require alignment not significant coordination.

3GPP Rel-17: Things to come



Stage 1 (Rel-17): So far

- Asset tracking
- Critical Medical Applications
- Unmanned Aerial Vehicles
- Audio Visual Service Production
- Maritime
- Extended Reality



Ongoing development will occur for

- Automotive, Railway, Maritime sectors
- Industrial Automation
- Critical Communications
- Fundamental enablers: IoT, Broadcast, Slicing, Network Automation, Orchestration and Management

Summary

- 📶 In Rel-16 adds 5G Vertical support
 - **Vehicle Communication, Mission Critical Communications, Industrial Automation and Verticals, Audio Visual Production,**
- 📶 Rel-16 also adds enhances the system
 - **5G LAN, High Precision Positioning, Cellular IoT for 5G, URLLC capabilities, Fixed and Satellite as 3GPP accesses, ONAP interworking, QoS Monitoring, Network Automation, protocol and core network improvements...**
- 📶 In Rel-17 – more verticals and service enablers
 - **logistics, e-health, unmanned aerial vehicles...**
 - **XR, ...**

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RWS-180023

Workshop on 3GPP Submission Towards IMT-2020

24-25 October 2018

Brussels, Belgium

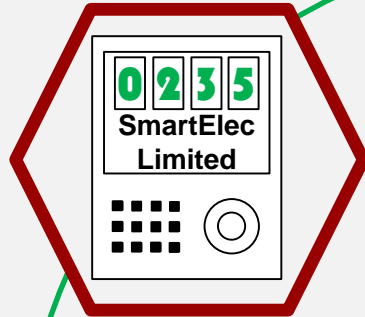


3GPP's Low-Power Wide-Area IoT Solutions: NB-IoT and eMTC

Low-power wide-area IoT

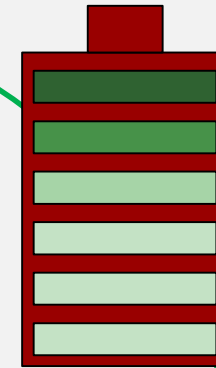
Connection density

1 000 000
UEs/km²



UE battery life

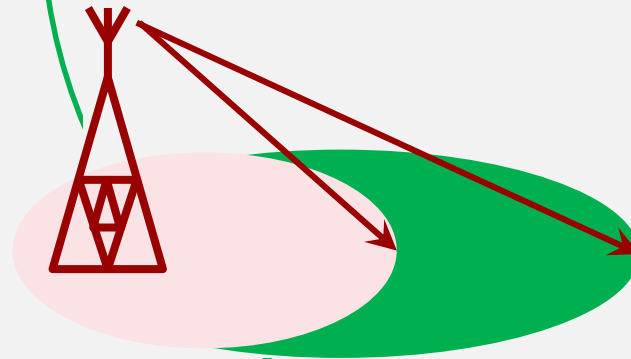
10 – 15 years in
164 dB MCL



Four KPIs for 3GPP LPWA IoT solutions

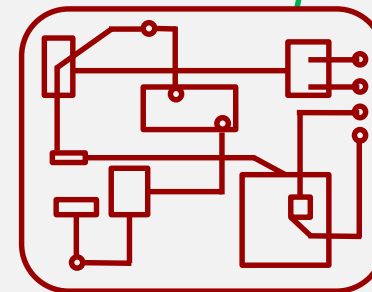
Coverage extension

164 dB MCL
@160 bps

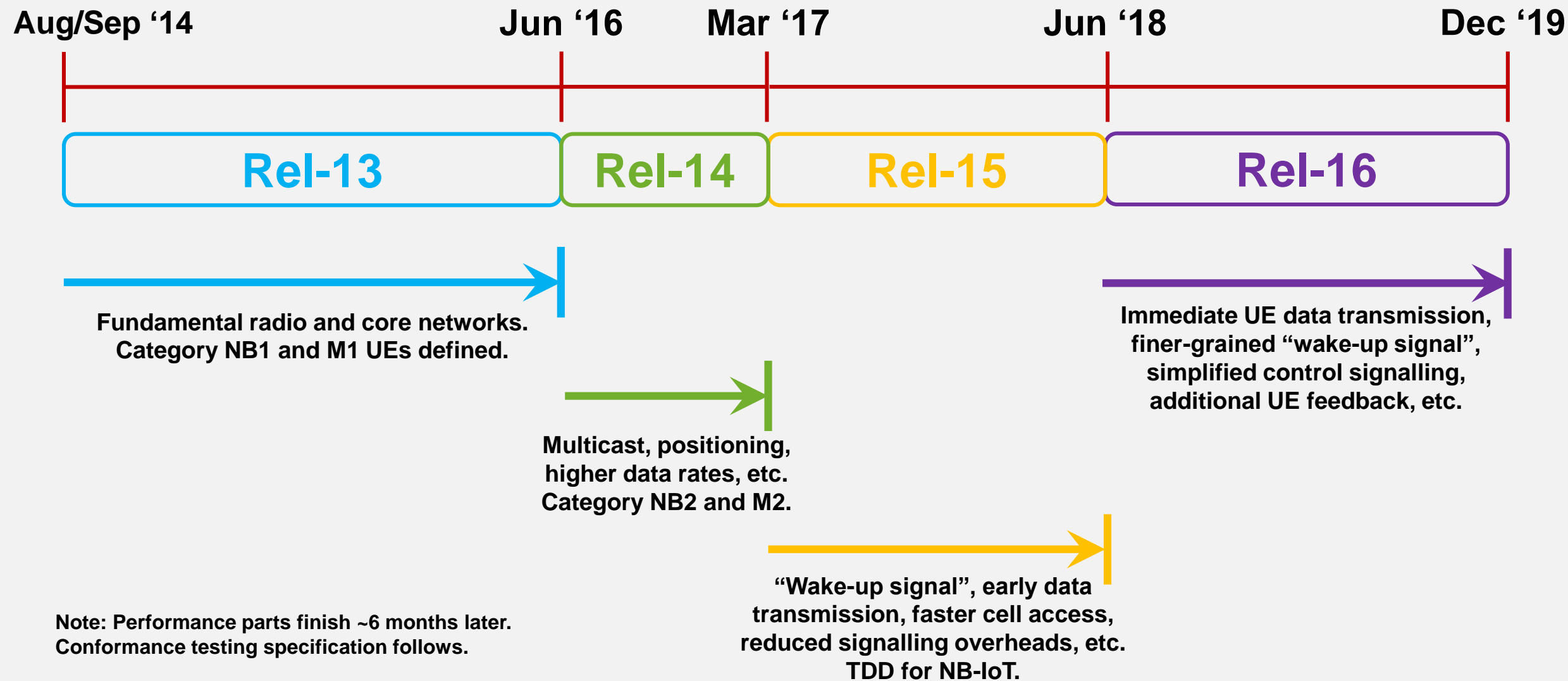


UE complexity and cost

Ultra-low

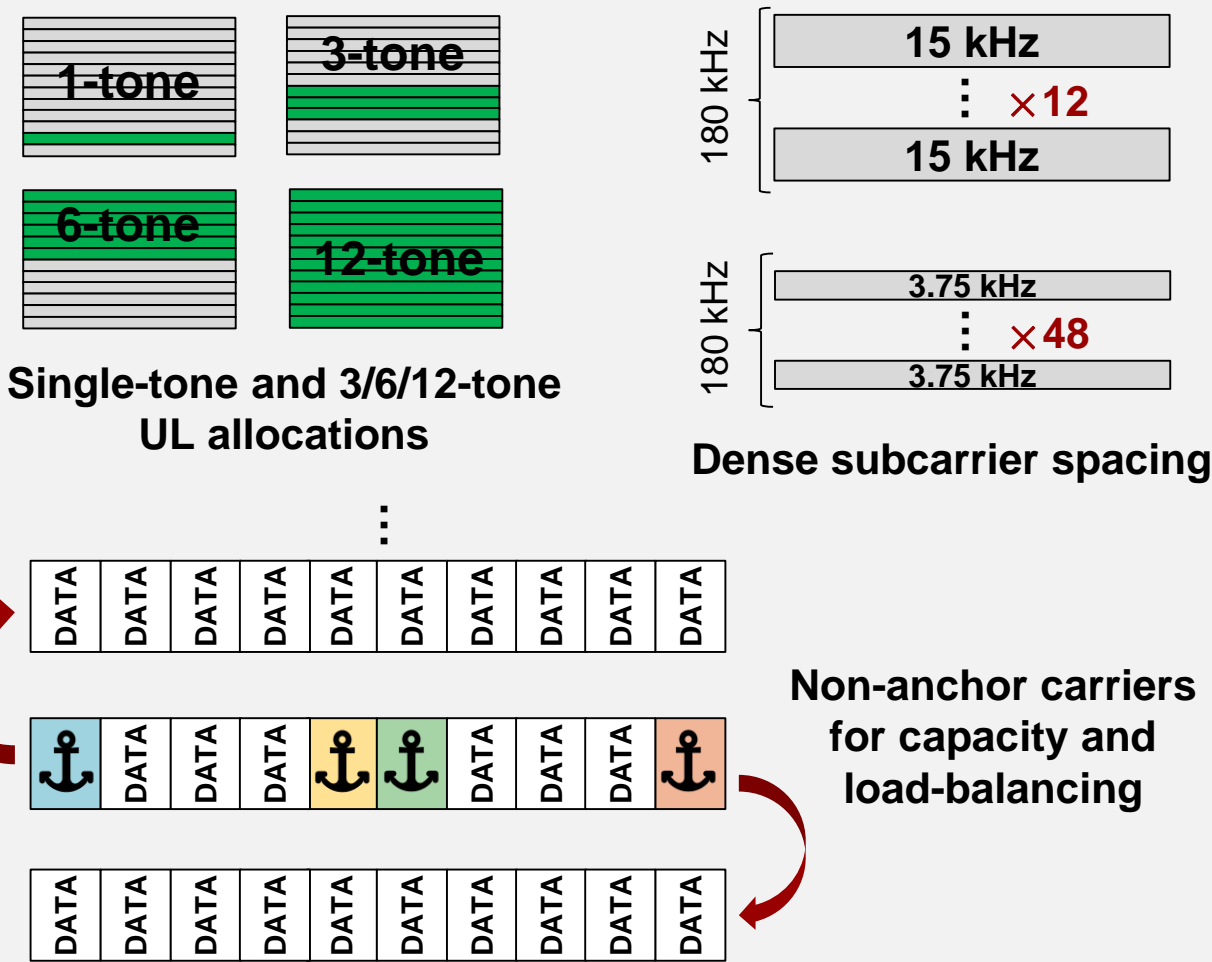


NB-IoT and eMTC project timelines

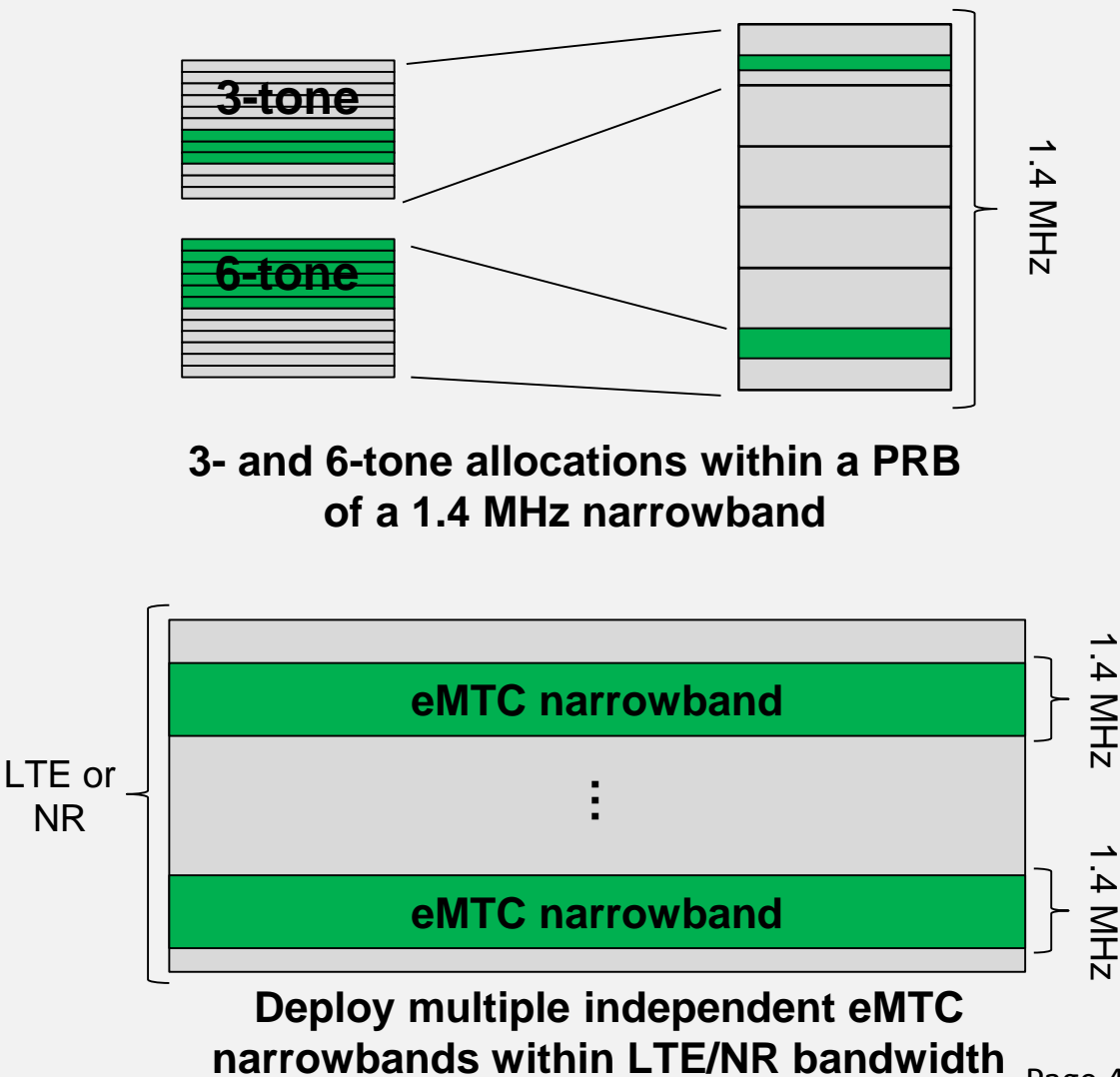


mMTC connection density

NB-IoT



eMTC



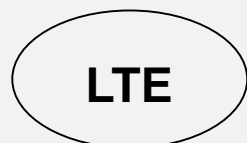
Ultra-low UE complexity: Signal processing simplifications

1 ms

0	1	0	1	0	1	1	1	0	0	1	0	1	0	1	0
1	1	0	0	1	0	0	1	1	0	0	1	0	1	0	1
0	1	1	0	1	0	0	1	1	0	1	1	1	1	0	1
1	1	0	1	0	0	1	0	1	0	0	0	1	0	1	0
0	1	0	1	1	0	1	1	0	0	1	1	0	0	1	1
0	1	1	1	0	1	1	0	0	1	1	0	0	1	1	0
0	1	1	1	0	1	0	0	1	0	1	0	1	1	0	1
1	1	1	0	1	1	1	1	1	0	1	1	1	0	1	1
1	0	1	0	0	1	0	0	1	1	0	0	1	1	0	1

Cat. 1 data

10 000 bits / ms



1 ms

?	?	?	?	?	?	?	?
?	?	?	?	?	?	?	?
?	?	?	?	?	?	?	?
?	?	?	?	?	?	?	?
?	?	?	?	?	?	?	?
?	?	?	?	?	?	?	?
?	?	?	?	?	?	?	?
?	?	?	?	?	?	?	?

Control channel

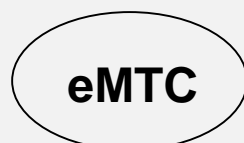
~40 candidates / ms

1 ms

1	0	1	1	1	0	1	1
0	0	0	1	0	0	1	0
1	0	0	0	1	0	0	0
0	1	1	1	0	1	1	0
0	1	1	0	0	1	0	1
1	1	0	1	1	1	1	0
1	0	1	0	1	0	0	1

Cat. M1 data

1000 bits / ms



1 ms

?	?	?	?
?	?	?	?
?	?	?	?
?	?	?	?
?	?	?	?

Control channel

~16 candidates / ms

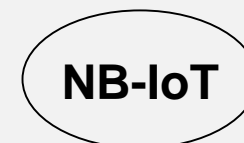
Up to 10 ms

1	0	1	1	1	1	0
1	1	0	0	0	1	0
0	1	0	1	0	0	0
1	0	0	1	0	1	1
1	0	1	0	0	0	1
1	0	0	1	0	1	1
1	0	1	0	0	1	1

Cat. NB1 data

UL: 1000 bits / up to 10 ms

DL: 680 bits / up to 10 ms



?
?
?
?

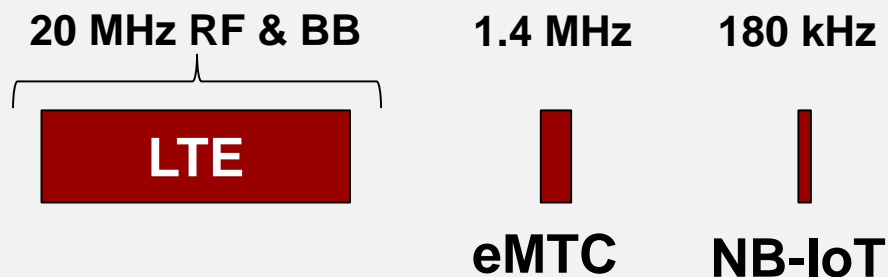
4 ms

✓

Control channel

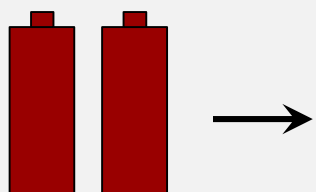
~1 candidate / ms

Ultra-low UE complexity: Hardware simplifications



RF bandwidth \Rightarrow RF hardware cost

BB bandwidth \Rightarrow signal processing cost

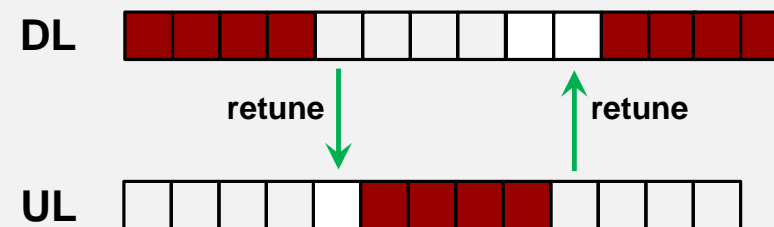


20 dBm and 14 dBm UE transmit power classes

Lower peak current requirement allows cheaper, smaller batteries



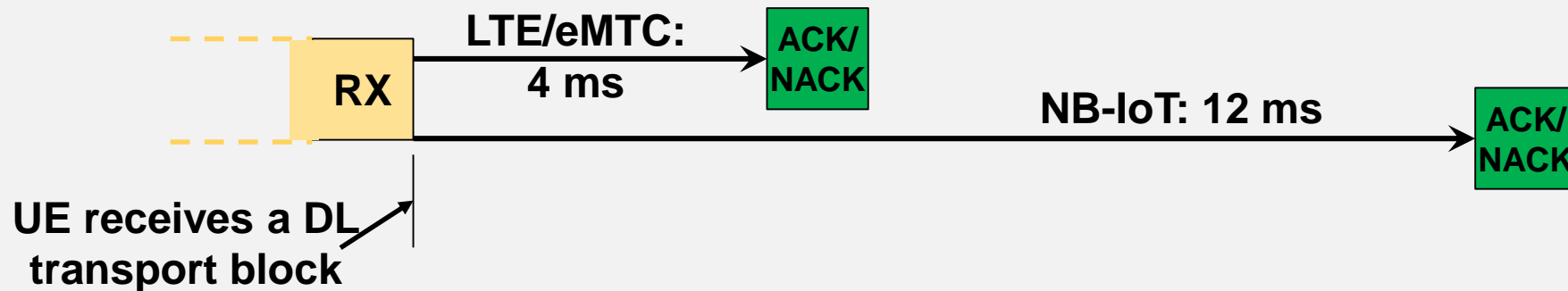
Single receive RF chain for UE



Half-duplex operation allows removal of duplexer from UE
(Mandatory NB-IoT, optional eMTC)

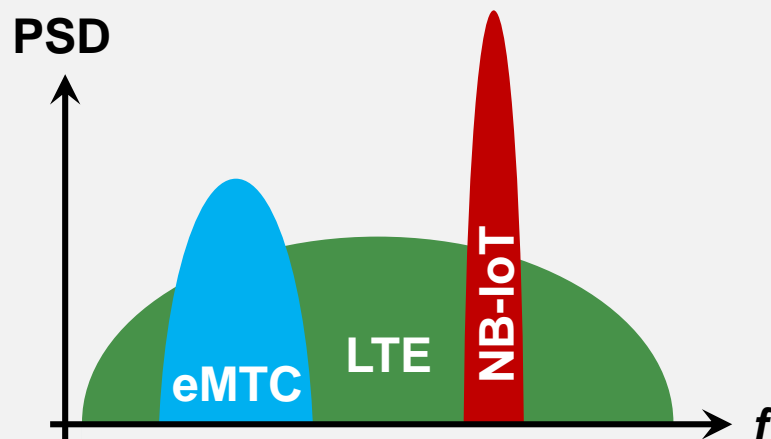
Ultra-low UE complexity: Further steps in NB-IoT

- NB-IoT takes additional steps to allow low-cost hardware:
 - Downlink uses convolutional encoding, removing need for turbo decoder in UE
 - 1 or 2 HARQ processes, instead of 8 in LTE/eMTC, reduces memory for data buffering
 - Synchronization signals with low complexity, optimised for reception in deep coverage
 - Maximum modulation is QPSK instead of 16-QAM, lessening EVM requirements
 - UE is allowed a much longer time to decode a reception before reacting to it, e.g. for DL:

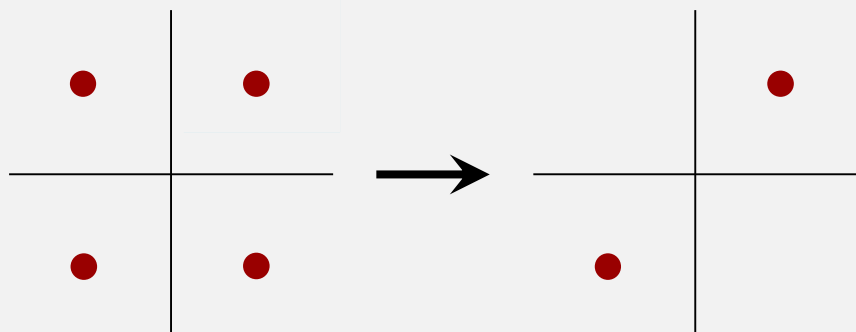


- 40 ms gap after each 256 ms of transmission during UL, allowing UE to re-sync to DL
 - Allows lower-cost non-temperature compensated crystal oscillators to be used in chipsets
 - Mandatory in NB-IoT UEs, optional for eMTC

Coverage extension

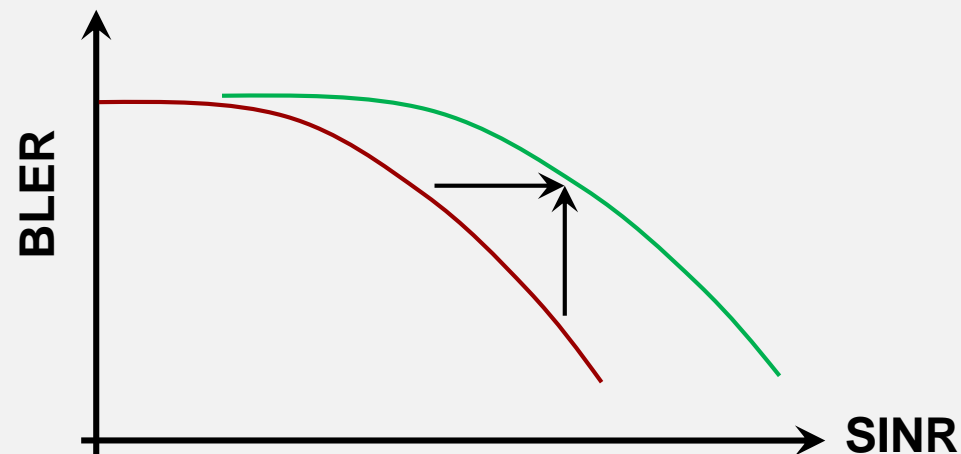
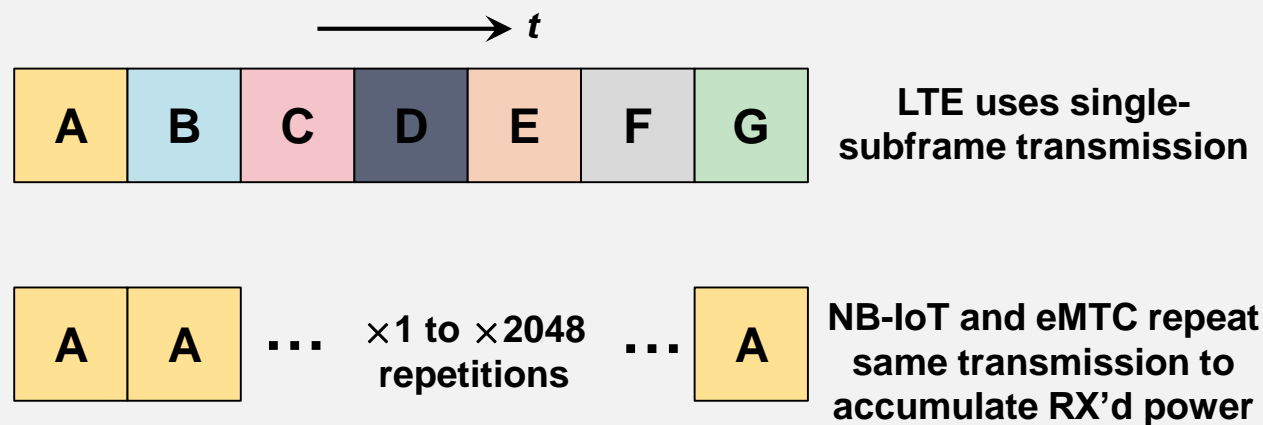


PSD boost in bandwidth as small as 3.75 kHz



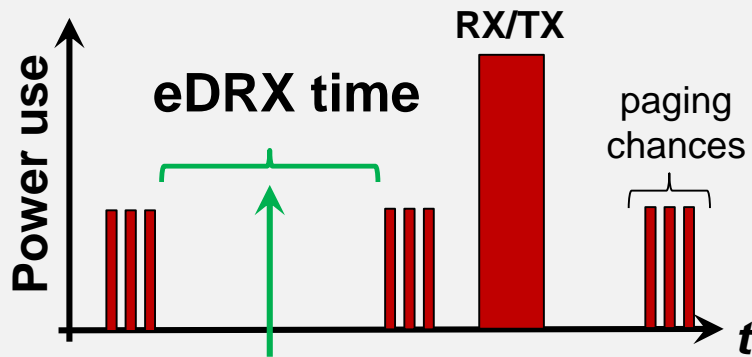
Low-PAPR $\pi/2$ -BPSK modulation
(and $\pi/4$ -QPSK in NB-IoT)

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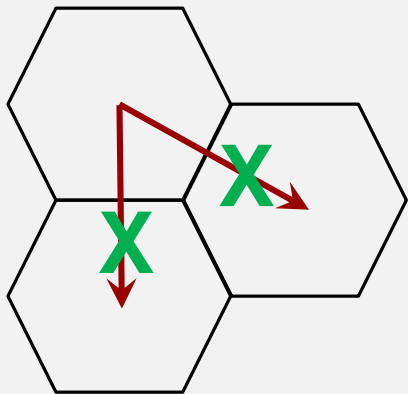
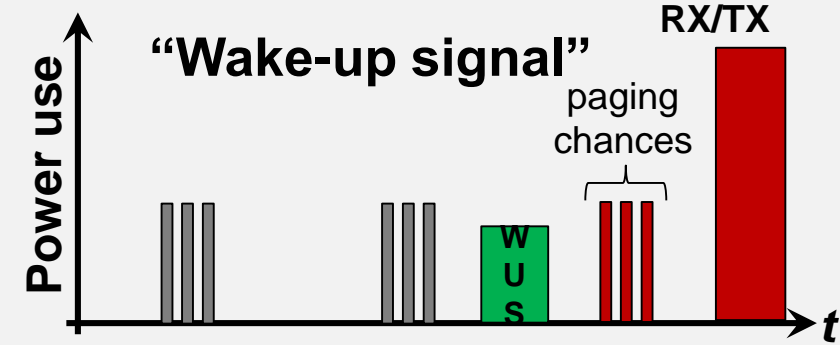
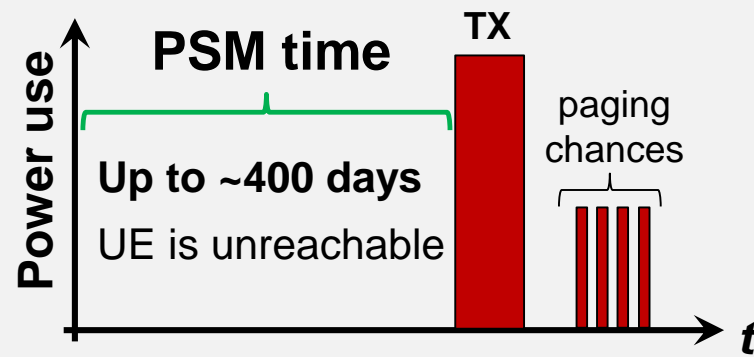


Relaxed requirements to tolerate lower SINR regimes

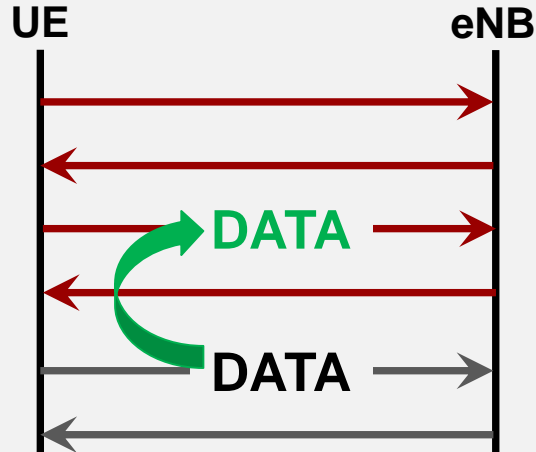
Battery life 10 – 15 years



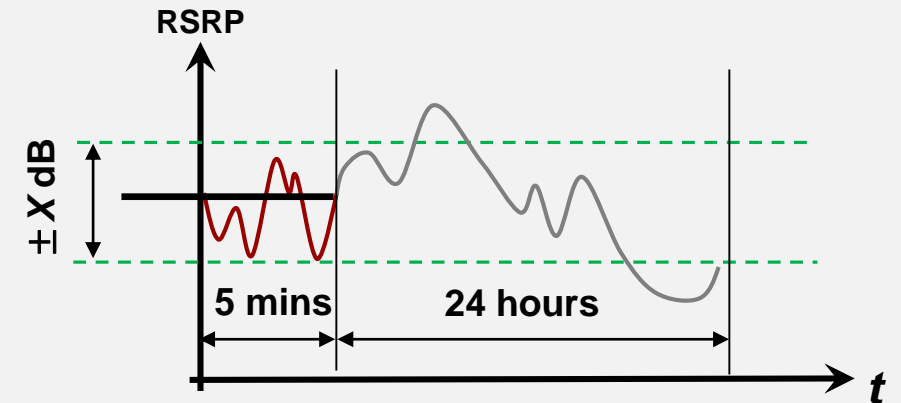
NB-IoT: ≤ 3 hr
eMTC: ≤ 40 min



NB-IoT: No handover
measurements / signalling



Earlier data transmission, without
tx/rx'ing to complete connection

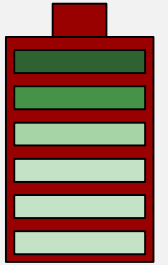


Stationary UE can suspend
measurements of neighbour cells

Hallmarks of 3GPP LPWA IoT technologies

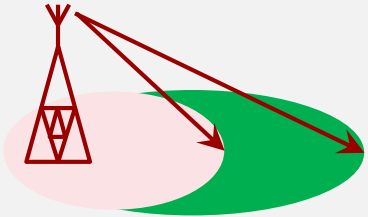
Battery life of 15 years or more on 2AA cells (5 Wh)

- Optimised for small infrequent packet transmissions e.g. 50-200 bytes few times/day
 - Transfer data earlier with fewer transmissions, and less battery consumption
- Maximise time UE can spend in low-power states and eliminate avoidable UE RX/TX



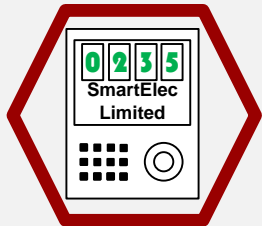
Support for normal to moderate coverage and deep coverage scenarios

- Repetition, PSD boosting, and low-PAPR transmissions
- In good coverage, NB-IoT and eMTC do not need repetitions



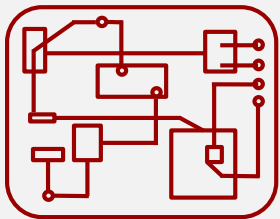
mMTC connection density of $\geq 1\,000\,000$ UE/km²

- Small resource allocations, 3.75 kHz subcarriers (NB-IoT), scalable network capacity
- Reduced signalling overhead to free-up resources for connecting more devices per cell



Complexity and cost is much lower than MBB devices

- Reduced RF and baseband bandwidths of 1.4 MHz for eMTC and 180 kHz for NB-IoT
- Relaxed signal processing requirements, with further relaxations in NB-IoT



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THANK YOU

www.huawei.com



**Workshop on 3GPP submission towards IMT-2020
Brussels, Belgium, October 24-25, 2018**

RWS-180024

Agenda Item: 6
Source: ETSI MCC
Title: **Draft** Report of Workshop on 3GPP submission towards IMT-2020,
Brussels, Belgium, October 24-25, 2018
Document for: Approval

****Draft** Report of Workshop on 3GPP submission
towards IMT-2020**

**held in Brussels, Belgium
October 24-25, 2018**



Keywords

RAN, 5G

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Meeting Organisation

Meeting:	Workshop on 3GPP submission towards IMT-2020		
Meeting location:	Belgium, Brussels		
	Albert Borschette Conference Centre (CCAB), Room 0A		
Duration:	Wednesday 24.10.18 (13:15) until Thursday 25.10.18 (17:00)		
Host:	European Commission		
Chairman:	Balázs Bertényi (Nokia, 3GPP TSG RAN chair)	email:	balazs.bertenyi@nokia.com
MCC support:	Joern Krause (ETSI)	email:	joern.krause@etsi.org
Documentation:	http://www.3gpp.org/ftp/workshop/2018-10-24_25_WS_on_3GPP_subm_tw_IMT2020/		
	(includes invitation, agenda, documents, Tdoc list, report)		

Chairman's foreword for this workshop

Welcome to the Workshop on 5G NR IMT2020 evaluation intended to present the details of the 5G NR radio interface as per the 3GPP Release 15 completed standards and the Release 16 planned features.

3GPP has been working extremely hard to bring 5G NR standards to the industry in an accelerated manner. Non-standalone 5G NR was completed in December 2017, and the corresponding ASN.1 has been stabilized in June/2018.

Standalone 5G NR was completed in June/2018, and the corresponding ASN.1 scheduled to be frozen in September/2018.

Some of the architecture options to facilitate migration from LTE to 5G NR will be completed in December/2018 still within Release 15.

3GPP has also approved the work program for Release 16 containing a host of new and enhanced functionalities for 5G NR. The target completion for Release 16 is December/2019. 3GPP submission to IMT2020 will contain both Release 15 and Release 16 functionality.

Balazs Bertenyi, Chairman of 3GPP RAN.

Executive Summary

The Workshop on 3GPP submission towards IMT-2020 was held in Brussels, Belgium, October 24-25, 2018, hosted by the European Commission. The meeting had 1xx participants (see Annex A) and 2x documents (see Annex B) and was intended to inform the Independent Evaluation Groups and the industry in general about the 5G mobile communication system and corresponding evaluations that 3GPP has and will submit as a candidate for IMT-2020 to ITU-R.

The workshop also had a live streaming service kindly provided by the host and announced shortly before the meeting via the 3GPP web page and the RAN reflector.

1 Opening of the meeting

As chairman of this workshop 3GPP TSG RAN chairman Mr. Balazs Bertenyi (Nokia) opened this workshop on 3GPP submission towards IMT-2020 on Wednesday October 24th, 2018 at 13:15.

1.1 Welcome from chairman of the workshop

RWS-180001 [Agenda of the Workshop on 3GPP submission towards IMT-2020, held Oct. 24-25, 2018 in Brussels, Belgium 3GPP TSG RAN chairman \(Nokia\)agenda](#)

presented by Mr. Balazs Bertenyi (10min)

Abstract: -

Discussion: -

Conclusion: The agenda was approved with the understanding that the real Wed schedule is shifted by 15min (later then what is in the agenda) due to some logistics as indicated by the host.

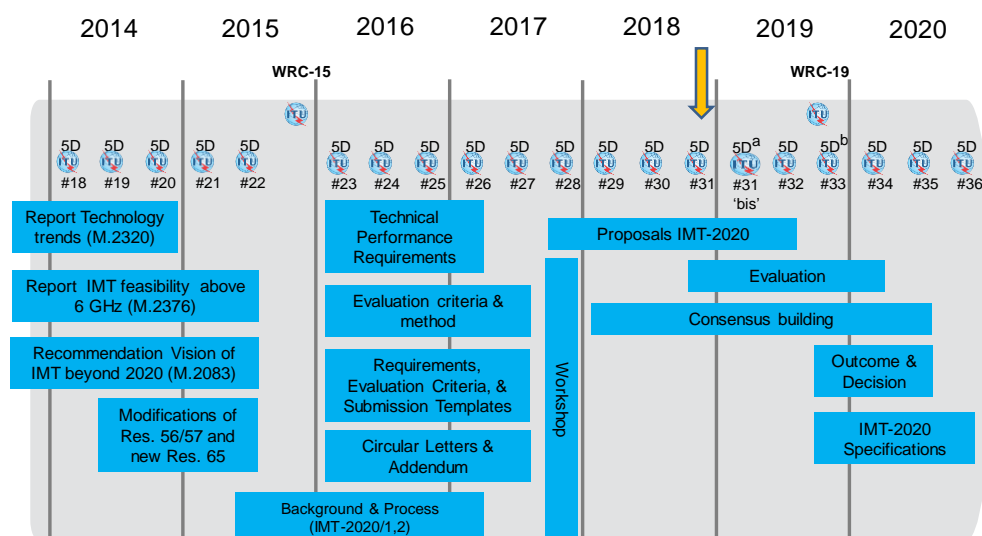
1.2 Welcome from ITU-R WP5D

RWS-180002 [Introduction by ITU-R WP5D](#) [ITU-R WP5D vice-chairman \(Ericsson\)](#) [discussion](#)

presented by Mr. Håkan Ohlsén (10min)

Abstract: The presentation gives the background, and plans onwards, describing the process for the development of IMT-2020. It also explains the timelines for technology proponents for IMT-2020 and for the Independent Evaluation Groups in this process for the completion of the Recommendation in year 2020.

Detailed Timeline & Process For IMT-2020 in ITU-R



(a) – five day meeting, (b) – focus meeting on Evaluation (Technology)

SUBMITTED PROPOSALS FOR IMT-2020

'3GPP' IMT-2020/3 (Rev. 2) SRIT: LTE+NR RIT: NR	'KOREA' IMT-2020/4 (Rev. 2) RIT: NR	'CHINA' IMT-2020/5 (Rev. 2) SRIT: LTE+NR RIT: NR	'DECT Forum & ETSI' IMT-2020/5 (Rev. 1) RIT: DECT-2020	'TSDSI' IMT-2020/7 (Rev. 1) SRIT: LTE+NR RIT: NR
------------------------------------------------------------------------------------------------	--------------------------------------------------------------------------	-------------------------------------------------------------------------------------------------	-------------------------------------------------------------------------------------------------	-------------------------------------------------------------------------------------------------

"RIT/SRIT Proponent":

Collectively 3GPP OPs
(ARIB, ATIS, CCSA, ETSI,
TTA, TTC, TSDSI)

Korea

China

DECT Forum & ETSI

TSDSI

- *Global collaboration and joint effort leads to success for IMT-2020 and 5G.*
- *ITU-R and industry partnerships remain strong and well aligned for IMT-2020 and 5G.*
- *Engagement by Administrations is high - both on spectrum and technology.*
- *ITU-R IMT-2020 vision continues as the global target in support of 5G.*
- *Initial IMT-2020 candidate radio interface technology submissions already being received – final submissions due July 2019.*
- *The Evaluation process has started! - advance activities already underway by independent evaluation groups.*
- *ITU-R Recommendation on detailed radio interface technology specifications for IMT-2020 on track for year-end 2020 release.*
- *ITU-R is well on schedule to implement all necessary procedures to identify the important future 'mm wave' spectrum (WRC-19) within the IMT overall spectrum portfolio.*

Discussion: 3GPP ITU-R ad hoc convener (Telecom Italia): slide 11: are there also self-evaluations planned/coming for the proposals from Korea, China and TSDSI
ITU-R WP5D vice-chairman (Ericsson): needs to check; later: for submission from China: NR+NB-IOT evaluation, for submission from Korea: 3GPP 5G evaluation, for submission from TSDSI: no extra input so far

Conclusion: noted

1.3 Welcome from the host

On behalf of the host, the European Commission, Mr. Bernard Barani, Deputy Head of Unit E1 of DG CONNECT - Future Connectivity Systems (standing in for Mr. Pearse O'Donohue (Director DG CONNECT "Future Networks")) welcomed the delegates to Brussels, Belgium and explained organisational issues of the meeting.

- Appreciates 3GPP's work achieved on 5G so far
- Still more efforts needed to better include vertical industry sectors in the 5th generation
- A cocktail will be served on Wed at 18:15 in front of the meeting room

RWS-180003 Welcome from the host Director CONNECT "Future Networks" (European Commission) discussion

Abstract: -

Discussion: -

Conclusion: withdrawn

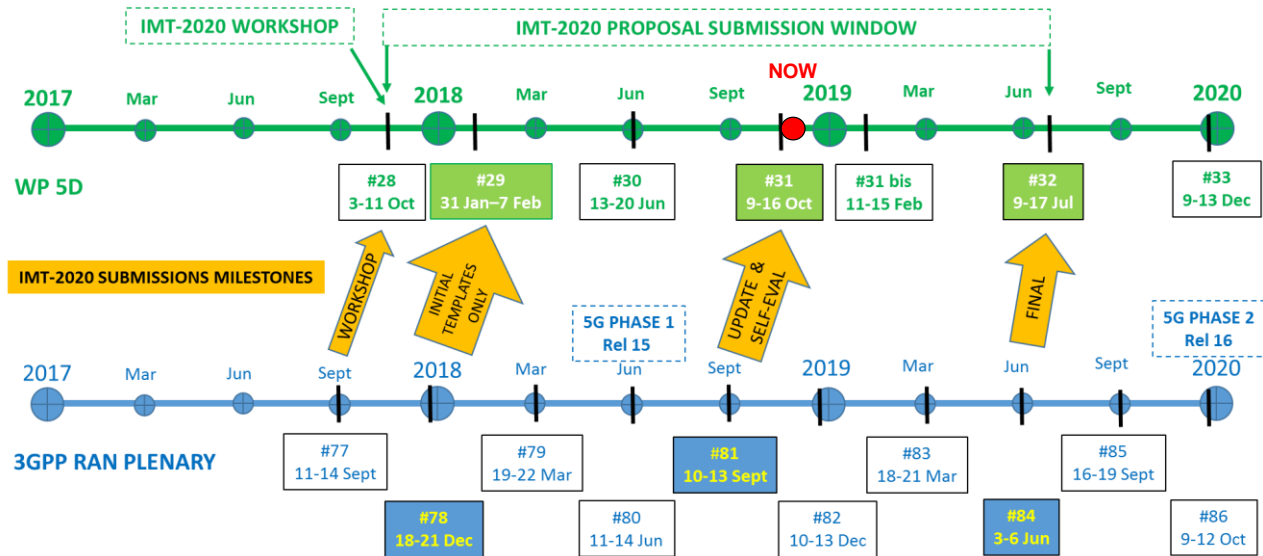
1.4 Explanation of 3GPP submission

13:55

RWS-180004 Explanation of 3GPP submission 3GPP TSG RAN ITU-R ad hoc convener (Telecom Italia) discussion
presented by Mr. Giovanni Romano (15min)

Abstract: This presentation provides the plans for the 3GPP submission for IMT-2020 with an initial submission end of 2017, an updated submission in autumn 2018 and a final submission to ITU-R WP5D in summer 2019.

IMT-2020 submission - timeplan



The updated description of 3GPP 5G and initial self evaluation can be found in [PCG41_08](#) and provides:

- characteristics template for SRIT and NR RIT
- compliance template for SRIT and NR RIT
- link budget
- preliminary self evaluation report (TR37.910 V1.0.0)

RIT: Radio Interface Technology, SRIT: Set of RITs

Discussion: -

Conclusion: noted

2 Specific technical features of the 3GPP proposal for 5G

2.1 Overview

2.1.1 RAN aspects

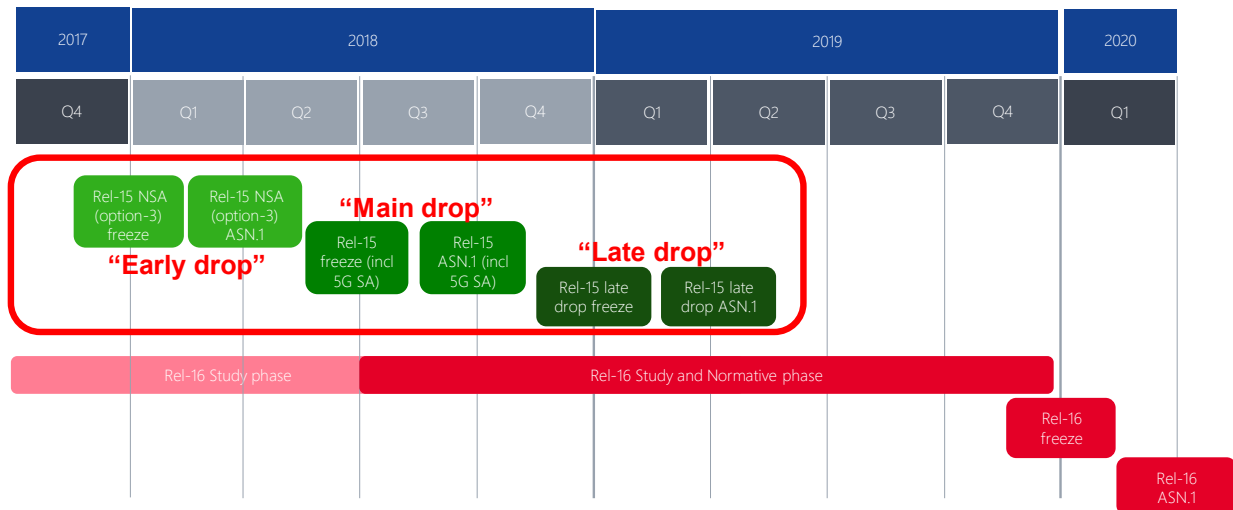
[RWS-180005](#) 3GPP proposal for 5G: Overview about RAN aspects 3GPP TSG RAN chairman (Nokia) discussion presented by Mr. Balazs Bertenyi (20min+5QA)

Abstract: 3GPP RAN has set out to design and specify a new Radio Interface Technology based on ITU requirements and based on commercial requirements identified in 3GPP. These requirements manifest in a holistic 5G vision – this vision guides the technology standards development. This presentation gives a high level overview of the main pillars of 3GPP's 5G NR, and its timelines.

- **5G vision** - for real: Perfect storm of multiple technology breakthroughs:
 - Low latency radio with fully flexible network
 - Artificial Intelligence and Automation
 - Device revolution for Augmented/Virtual Reality
 - Vertical industries going wireless
- **What is 5G NR?**

- Operation from low to very high bands: 0.4 – 100GHz; including standalone operation in unlicensed bands
- Ultra wide bandwidth: Up to 100MHz in <6GHz; up to 400MHz in >6GHz
- Set of different numerologies for optimal operation in different frequency ranges
- Native forward compatibility mechanisms
- New channel coding: LDPC for data channel, Polar coding for control channel
- Native support for Low Latency and Ultra Reliability
- Flexible and modular RAN architecture: split fronthaul, split control- and user-plane
- Native end-to-end support for Network Slicing (addressing needs of vertical markets)

3GPP Timeline



Discussion: -

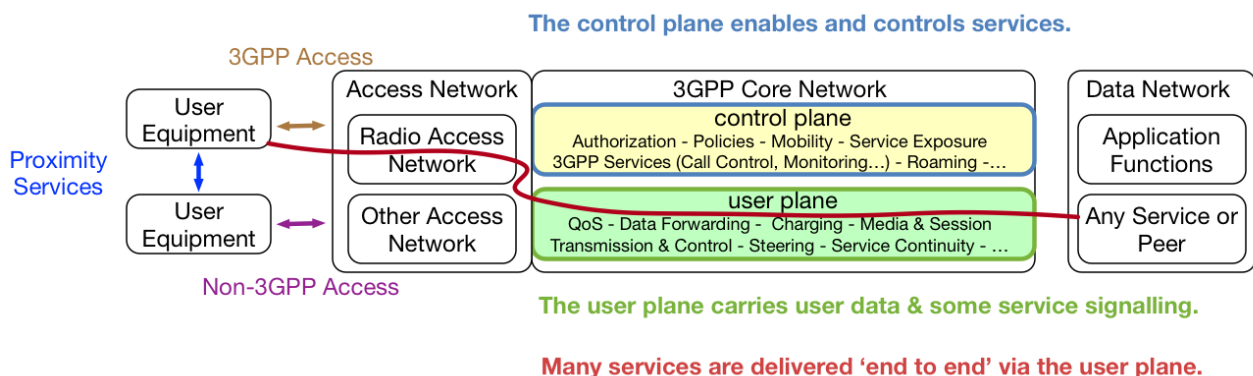
Conclusion: noted

2.1.2 System and Core network aspects

[RWS-180006 System and Core Network Aspects](#) 3GPP TSG SA chairman (Samsung) [discussion](#)
presented by Mr. Erik, Guttman (20min+5QA)

Abstract: The 5G System supports diverse services and requirements as a result of advances in the Core Network architecture and the addition of new enabling technologies. This talk introduces 5G Phase 1 and 2 from a system and service perspective, elaborating the key advances from the 4G System.

3GPP System:



Software- and Service-centric Transformation:

- One CoreNetwork fits all => Open & Flexible Enabler
- Telecom Operators => Multiple Stakeholders
- Phones => Things

- *Procedures => Services*
- *Static Topology => On-demand Resources*
- *Dedicated Hardware => Orchestrated Resources*
 - *Network Function => Virtualization*
 - *Single Network => Slice*

5G Core Technologies (subset):

- *Orchestration and Virtualization (NFV) – de-couple logical function from hardware*
- *Slicing – logical end-2-end networks tailed to customer needs*
- *Edge Computing (MEC) – resources where they are needed (URLLC)*
- *Exposure (API) – 3rd party access to 5G services*
- *Service Based Architecture (SBA) – stateless, open, flexible*
- *Harmonized Protocols & Access Agnostic – generic solutions*

Discussion: OnFace: slide 8: can UEs talk to each other without the network?
SA chairman: slide 8 is not the real 5G architecture, TS 23.501 provides the 5G architecture, proximity services were introduced in REL-11, if under 3GPP coverage it is managed by the network; same functionality is also relevant for V2X in Rel-16
European Commission: slices possible across 2 different operators? what are the limits?
SA chairman: 4G has dedicated core networks, device can use 1, 5G introduces slicing which is much more flexible

Conclusion: noted

2.2 NR physical layer design

2.2.1 Physical layer structure, numerology and frame structure, NR spectrum utilization mechanism

[RWS-180007 NR Physical layer design: Physical layer structure 3GPP TSG RAN WG1 vice-chairman \(Ericsson\) discussion](#)

presented by Mr. Havish Koorapaty (40min+5QA)

Abstract: An overview of the physical layer aspects of NR design is provided. The key features of NR that enable utilization of a wide range of spectrum and enable NR to serve a broad set of use cases are described. Physical layer aspects discussed include the frame structure, numerology, transport and control channel structure and procedures, and initial access signals, channels and protocols.

- *NR addresses a broad range of use cases with a flexible physical layer structure*
- *Key enablers include*
 - *Ultra-lean design*
 - *Operability in a wide spectrum range*
 - *Low latency*
 - *Forward compatible design*
 - *Advanced multi-antenna techniques*

Discussion: RAN1 vice-chairman (Ericsson): LTE: started with voice and mobile broadband first, just later IOT, vehicular etc. came; NR is much more flexible
OnFace: which technology/use case is considered for mm wave?
RAN1 vice-chairman (Ericsson): NR is a single framework which will be able to address different frequency ranges and use cases
OnFace: other technologies can be added?
RAN1 vice-chairman (Ericsson): may be better to see next presentation about antenna techniques
Samsung/5GPPP: any soft combining techniques for HARQ?
RAN1 vice-chairman (Ericsson): similar to LTE, soft buffer techniques are different

Conclusion: noted

2.2.2 NR MIMO

RWS-180008 NR physical layer design: NR MIMO 3GPP TSG RAN WG1 vice-chairman (Samsung) discussion presented by Mr. Younsun Kim (25min+5QA)

Abstract: The presentation is on the multi-antenna specification features in Rel-15 NR. It includes key NR-MIMO features such as uplink/downlink transmission schemes, multi-beam operation, and reference signal designs.

Comparison of NR-MIMO vs LTE MIMO

	LTE Rel-8	LTE-A Pro Rel-15	NR Rel-15
Purpose	<i>Spectral efficiency enhancement</i>	<i>Spectral efficiency enhancement</i>	<ul style="list-style-type: none"> - Coverage enhancement (especially for above 6GHz) - Spectral efficiency enhancement
Multi-beam operation	<i>No specification support</i>	<i>No specification support</i>	<ul style="list-style-type: none"> - Beam measurement, reporting - Beam indication - Beam failure recovery
Uplink transmission	<ul style="list-style-type: none"> - Up to 4 layers per UE - Up to 8 layers for MU-MIMO (cyclic shifts for ZC-sequence) 	<ul style="list-style-type: none"> - Up to 4 layers per UE - Up to 8 layers for MU-MIMO (cyclic shifts for ZC-sequence) 	<ul style="list-style-type: none"> - Up to 4 layers per UE - Up to 12 layers for MU-MIMO (orthogonal ports)
Downlink transmission	<i>Up to 4 layers per UE</i>	<ul style="list-style-type: none"> - Up to 8 layers per UE - Up to 4 layers for MU-MIMO (orthogonal ports) 	<ul style="list-style-type: none"> - Up to 8 layers per UE - Up to 12 layers for MU-MIMO (orthogonal ports)
Reference signal	<ul style="list-style-type: none"> - Fixed pattern, overhead - Up to 4 TX antenna ports (CRS) 	<ul style="list-style-type: none"> - Fixed pattern, overhead - Up to 32 TX antenna ports (CSI-RS) 	<ul style="list-style-type: none"> - Configurable pattern, overhead - Up to 32 TX antenna ports (CSI-RS) - Support for above 6GHz

Discussion: RAN1 vice-chairman (Samsung): The exact enhancements on NR-MIMO for Rel-16 are still a bit under discussion in 3GPP as the release has just started

OnFace: Qualcomm announced a 28GHz band chip, is it compliant with this?

Samsung: there are chips for 28GHz on the market which will be compliant with 5G standards

Samsung/5GPPP: slide 19: slots or ms to specify periodicity?

RAN1 vice-chairman (Samsung): slots, but periodicity is flexible

OnFace: slide 16: how fast is recovery?

RAN1 vice-chairman (Samsung): no exact figure at the moment but a fraction of the initial RACH

5GPPP: slide 7: how flexible is this?

RAN1 vice-chairman (Samsung): how fast beam changes depends on gNode B implementation

Conclusion: noted

2.3 NR architecture

RWS-180009 NR architecture 3GPP TSG RAN WG3 chairman (Ericsson) discussion presented by Mr. Gino Masini (25min +5QA)

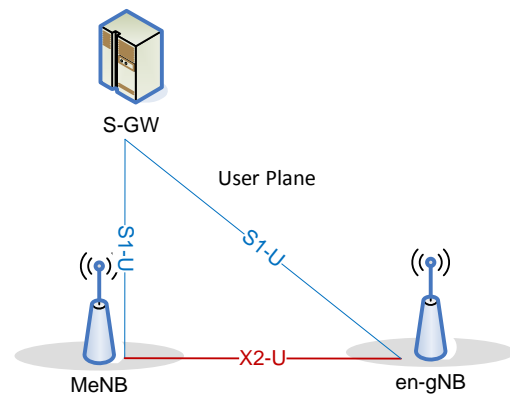
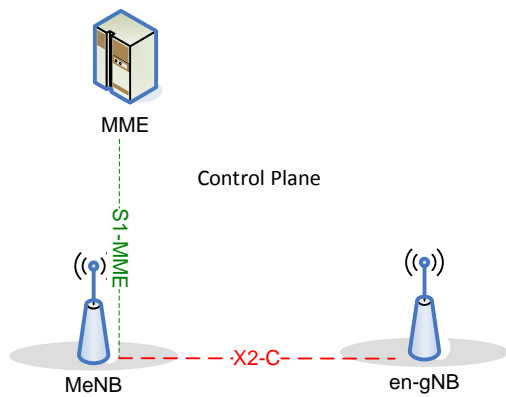
Abstract: Overview of the 5G Radio Access Network (NG-RAN) architecture and key protocols as defined by 3GPP. It introduces the overall architecture, migration path options, 5G base station architecture, and key network protocols. The interfaces and protocols specified by 3GPP facilitate the migration and evolution of 4G to 5G in a cost-efficient way, while also helping the uptake of NR and the 5G Core network to deliver new services.

Option 3 (“EN-DC”):

eNB as MN (master node), connected to LTE core network

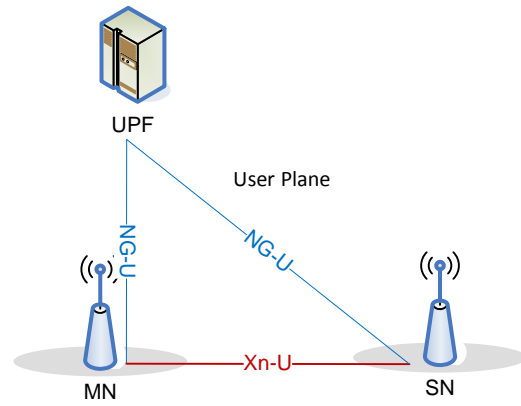
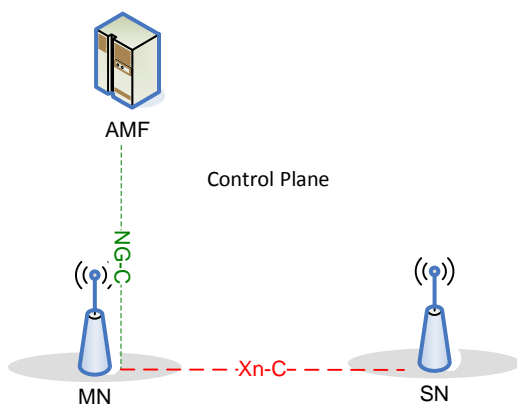
“en-gNB” as SN (secondary node)

Only a subset of 5G radio functionality is needed for this use



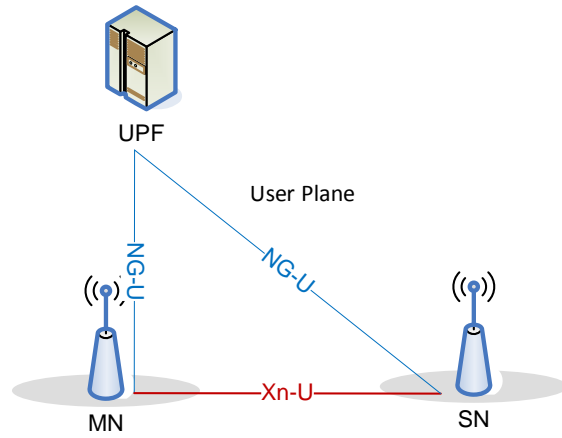
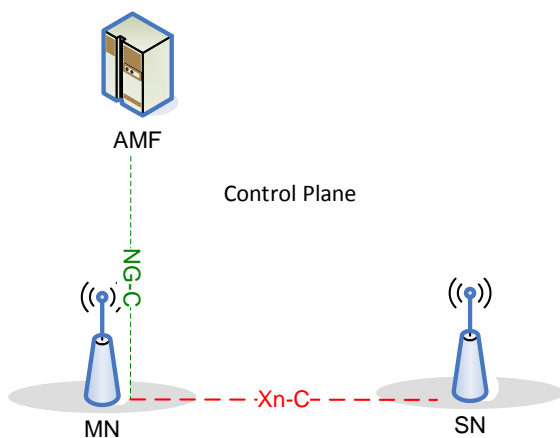
Option 4 ("NE-DC"):

gNB as MN, connected to 5G core network
ng-eNB as SN



Option 7 ("NGEN-DC"):

ng-eNB as MN, connected to 5G core network
gNB as SN



Discussion: RunEL: home eNode B addressed here?

RAN3 chairman (Ericsson): the question is fair: why is there no home gNB? The answer is that people (esp. operators) think that what we have is enough to also support home Node B functionality; on core network side they study CSG aspects

RunEL: looking at all use cases and the traffic increase this is a bit strange

SA chairman (Samsung): what we implemented for home Node Bs in LTE is covered with the flexible approach for 5G, so it is included

OnFace: slide 10: Japan will put PHS out of service in 2020, option 3 will not work if LTE is no longer in service

RAN3 chairman (Ericsson): there are other architecture options so that the operators will be able to pick acc. to their deployment plans

Conclusion: noted

end of Wednesday/beginning of Thu: 9:00

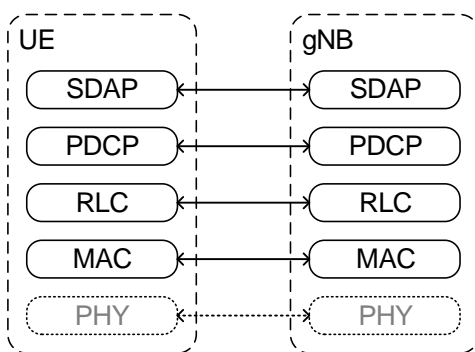
2.4 NR protocol

[RWS-180010 NR radio interface protocols](#) [Intel](#) [discussion](#)

presented by Mr. Sudeep Palat (25min+5QA)

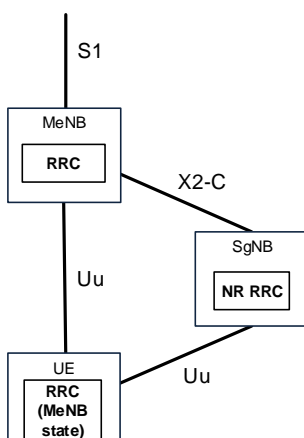
Abstract: Provides an overview of NR radio interface architecture and protocols for control and user plane covering RRC, SDAP, PDCP, RLC and MAC, focussing on differences and performance benefits compared to LTE. RRC states and state transitions with reduced transition delays are also discussed. A brief look at Rel-16 topics under discussion is also provided.

User plane protocol stack:



- NR PDCP, RLC and MAC are all new protocols but share many similarities with corresponding LTE protocols
- SDAP protocol introduced to support new flow based QoS model of the 5GC

Control plane for EN-DC (non standalone NR):

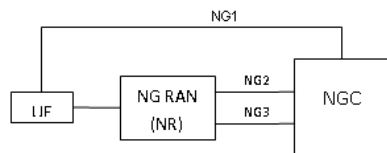


Dual connectivity:

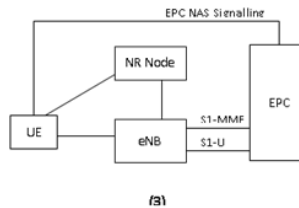
- Master Node (MN):
 - Overall master, responsible for connection establishment with UE, connection to Core network, handover etc.
 - Master Cell Group (MCG) for UE
 - For EN-DC, MN is an LTE eNB
- Secondary Node (SN)
 - Secondary Cell Group (SCG) for UE
 - For EN-DC, SN is an NR gNB

MCG = Master Cell Group, SCG = Secondary Cell Group

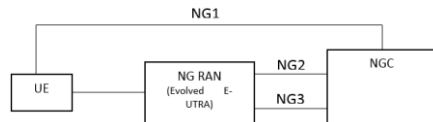
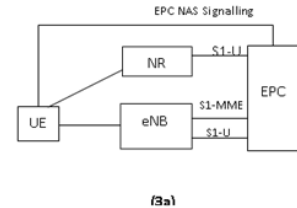
Deployment options:



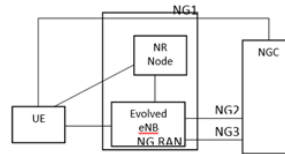
Option 2 – NR Standalone



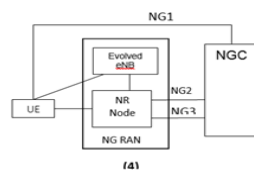
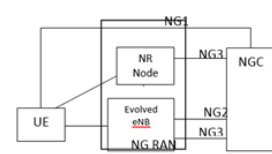
Option 3 – Non Standalone (EN-DC)



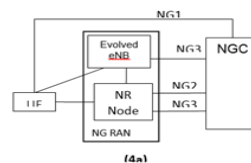
Option 5 – Evolved E-UTRA standalone



Option 7 – NSA with NG Core (NG-EN-DC)



Option 4 – NE DC



Discussion: RunEL: relation ship: bearer/GTP-U tunnel and slices?
 Intel: no relation in 5G (for LTE there was a 1-1 relation, we broke this concept for 5G, we have a new QoS concept; GTP-U tunnel is rather a CT topic
 CT chairman (Huawei): CT4 has a study on alternatives for GTP-U
 Conclusion: noted

2.5 NR radio frequency and co-existence

RWS-180011 NR radio frequency and co-existence 3GPP TSG RAN WG4 chairman (Samsung) discussion
 presented by Mr. Xutao Zhou (25min+5QA)

Abstract: In Rel-15 NR, RAN4 has specified radio frequency system parameters and transmitter/receiver characteristics for both UE and BS. In this presentation, frequency bands and general system parameters specified in RAN4 Rel-15 specification are introduced. Furthermore, UE and BS RF requirements related to sharing and co-existence performance including output power, unwanted emission, sensitivity and blocking are presented.

RF Requirements

- | RF specification for UE (**38.101-1/2/3**) and BS (**38.104**)
 - Operating bands and Channel arrangement
 - Transmitter RF requirements
 - Receiver RF requirements
- | EMC specification for UE (**38.124**) and BS (**38.113**)
 - EMC emission
 - EMC Immunity
- | MSR BS RF requirements (**37.104**)
 - RF requirements for Multi-Standard Radio BS

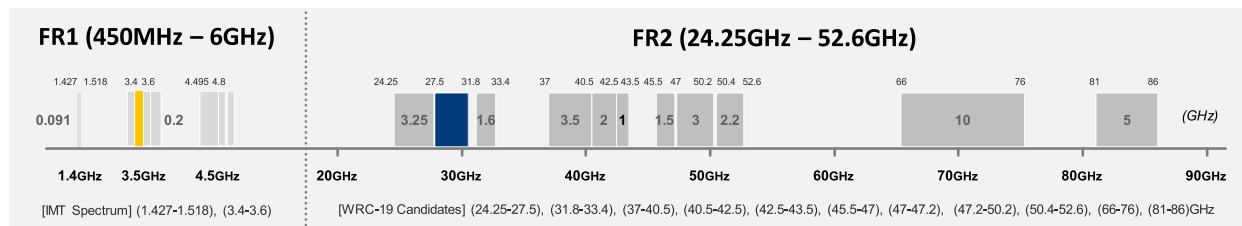
Baseband Requirements

- | Radio Resource Management (**38.133**)
 - Mobility
 - Timing
 - Measurement
- | UE (**38.101-4**) Demod/CSI and BS (**38.104**) Demod
 - PDSCH/PDCCH/SDR
 - PUSCH/PUCCH/PRACH
 - CSI/PMI/RI
 - CRI
 - Other PHY channel
 - Other channel state information

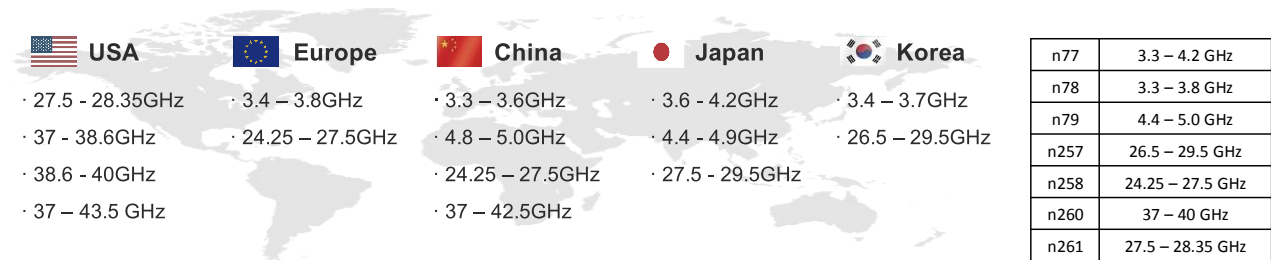
Test

- | BS conformance Test
 - Conducted Test (**38.141-1**)
 - Radiated Test (**38.141-2**)
- | NR test method (**38.810**)
 - RF testing method
 - RRM testing method
 - Demodulation Testing method

5G Candidate frequency bands for ITU-R WRC-19 (Nov. 2019)



New 5G frequency allocation status



Use prefix "n" to differentiate from E-UTRA bands and UTRA bands

BS1-C: conducted, BS1-H: hybrid, BS1-O: over the air (OTA)

Discussion: TCCA: 700 and 800MHz for emergency, nowadays also 450MHz so coverage is important; what limitations for 2x5MHz, 2x10MHz will they have for MIMO etc.?
 RAN4 chairman: dedicated frequency bands for certain regions
 RAN chairman: some MIMO functions will bring spectrum efficiency; step from TETRA to LTE was the big step, step from LTE to 5G will be a small step
 Ericsson: features are not limited for certain frequency allocations e.g. to small bandwidth allocation or lower frequency range, but of course for lower frequencies antenna dimensions will get bigger
 RAN chairman: 5G direct mode will be addressed under V2X which has more stringent requirements
 SA chairman: 5G will include already enhancements that came in 4G step by step but there will be further enhancements (orchestration, satellite, ...)
 TCCA: slicing does not really apply to 700MHz?
 RAN chairman: you will not slice 700MHz but a critical communication network may be a separate extra slice in a commercial network
 Ericsson: slicing is an end-to-end concept
 Telecom Italia: is RAN4 considering NB-IOT in guard band for new radio (as it was in LTE)?
 RAN4 chairman: coexistence for NB-IOT has not yet started
 Fujitsu: slide 4: Japan 27.5GHz is now extended to 27GHz and is now overlapping with another band, this will be brought up in RAN4
 RAN4 chairman: yes, can be considered in RAN4, we have regional requirements

Conclusion: noted

2.6 NB-IoT, eMTC, and LTE evolution

2.6.1 NB-IoT, eMTC

RWS-180012 3GPP's Low-Power Wide-Area IoT Solutions: NB-IoT and eMTC Huawei discussion

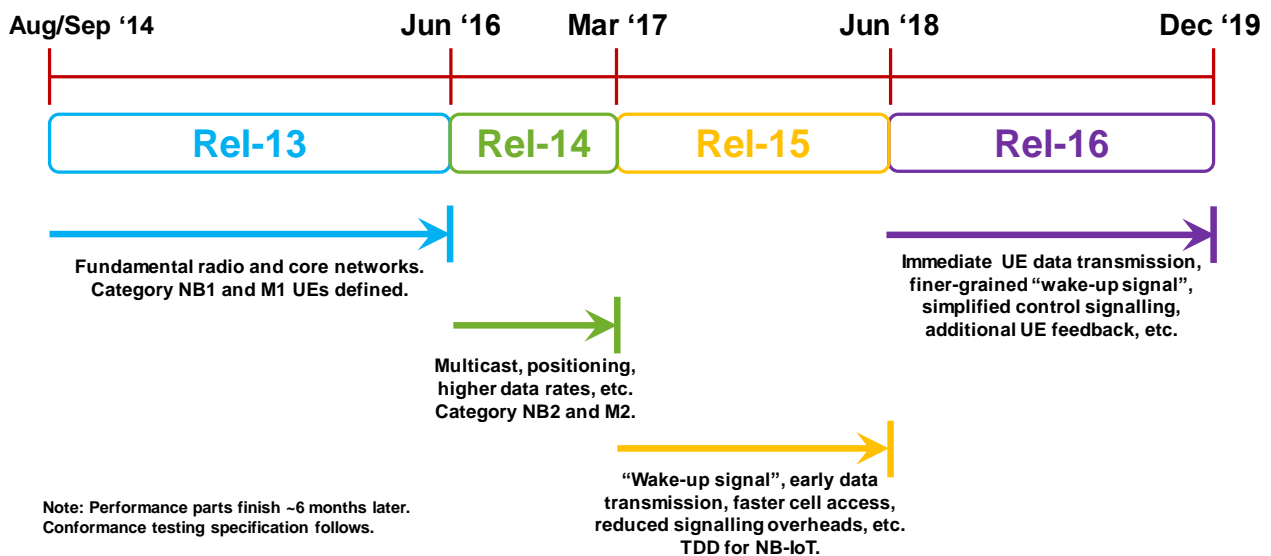
Conclusion: revised in RWS-180023 (same contents, just slide template updated)

RWS-180023 3GPP's Low-Power Wide-Area IoT Solutions: NB-IoT and eMTC Huawei discussion

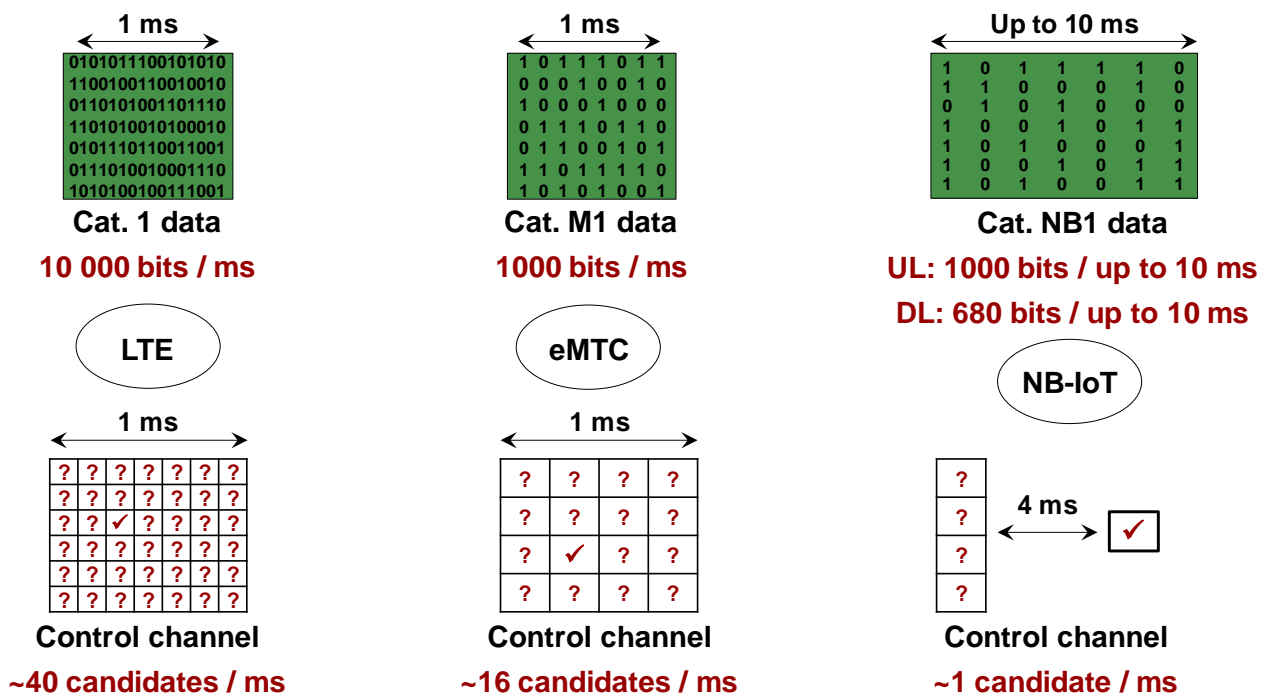
presented by Mr. Matthew Webb, Huawei (20min+5QA)

Abstract: 3GPP has developed two cellular technologies for low-power wide-area IoT: NB-IoT and eMTC. This presentation explains the four main targets of low device complexity, extended coverage, long battery life, and massive connection density that were used in the design of both technologies, and the solutions that were introduced to meet them.

NB-IOT and eMTC project timelines:



Ultra-low UE complexity: Signal processing simplifications



cat.1 is lowest LTE UE category

Hallmarks of 3GPP LPWA IoT technologies:

- Battery life of 15 years or more on 2AA cells (5 Wh)
- Support for normal to moderate coverage and deep coverage scenarios
- mMTC connection density of $\geq 1\,000\,000$ UE/km²
- Complexity and cost is much lower than MBB devices

Discussion:

- OnFace: QPSK is used, offset QPSK would be even better
- Huawei: actually we did something like this
- European Commission: NB-IOT will be part of the 5G submssion?
- Huawei: 3GPP submits NR+LTE and NB-IOT & eMTC is part of LTE, so it will be included
- European Commission: so in NR alone there is no plan to include a similar NB-IOT functionality so far?

Huawei: no plan in REL-16 of 3GPP since NB-IOT is supposed to have a 20 years life time but maybe in a future release

Conclusion: noted

2.6.2 LTE evolution

[RWS-180013](#) [LTE evolution](#) [Ericsson](#) [discussion](#)

presented by Mr. Asbjörn Grövlén (20min+5QA)

Abstract: An overview of the technical features introduced in LTE since the 3GPP submission to IMT-Advanced, excluding NB-IoT and eMTC. This comprises releases 11 through 15 and includes CoMP, enhanced downlink control, dual connectivity, D2D/V2X, small cell enhancements, LAA, sTTI, Elevation Beamforming and Full-Dimension MIMO, L2 latency reduction and shortened TTI and processing time.

- *LTE is submitted as part of the SRIT to IMT-2020*
- *What has happened in LTE since the IMT-Advanced submission? Continuous enhancements have improved LTE meeting the IMT-2020 requirements of a component RIT:*
 - *Coordinated Multi-Point Operation (REL-11 =>)*
 - *Enhanced downlink control channel (REL-11=>)*
 - *Dual connectivity (from REL-12=>)*
 - *Small Cells (REL-11=>)*
 - *Proximity services (ProSe) and vehicle-to-everything (V2X) (REL-12=>)*
 - *Licensed-Assisted Access (REL-13=>)*
 - *Elevation Beamforming/Full-Dimension MIMO (REL-13=>)*
 - *Shortened TTI and processing time (REL-15=>)*

Discussion: OnFace: slide 7: sidelink for UE-UE communication, MAC must be different for UE-UE than for UE-BS communication

Ericsson: yes, but we tried to reuse as much as possible

Dep. of Communications (DCCA): wondering why 3GPP went for a new standard for vehicular as there was an existing CITS standard, we have now to competing technologies

RAN chairman: originally CITS was limited to safety cases while the goals for 3GPP were much larger than this, LTE eco-system has grown a lot to worldwide system with corresponding benefits

Ericsson: 3GPP came from public safety into this topic, 3GPP is competing in a number of areas, technologies within and outside of 3GPP

Dep. of Communications (DCCA): while UEs may be changed every 2 years, the lifetime of cars is much higher and also investments in the infra-structure is needed

Conclusion: noted

3 IMT-2020 submission templates

3.1 Overview of 3GPP submission and compliance to IMT-2020 requirements

[RWS-180014](#) [IMT-2020 submission templates: Overview of 3GPP submission and compliance to IMT-2020 requirements](#) [Huawei](#) [discussion](#)

presented by Mr. Yong Wu (10min+5QA)

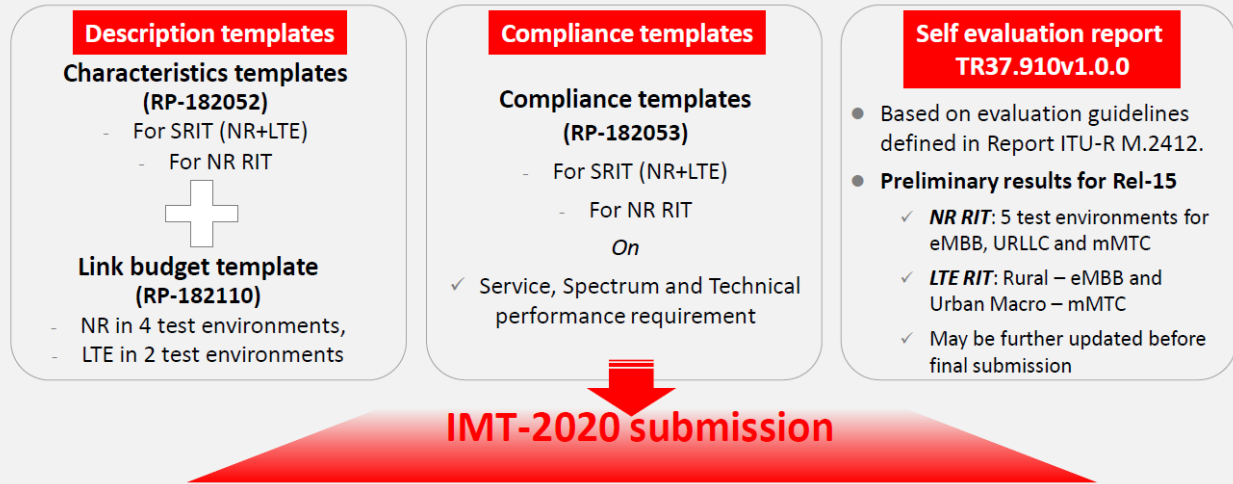
Abstract: The overview of 3GPP submission is provided in this presentation to give a general view on how 3GPP 5G achieves IMT-2020 requirements. It includes the introduction of 3GPP 5G SRIT and RIT submission, the submission templates as well as self evaluation report. The assessment results of compliance to IMT-2020 requirements are provided.

3GPP submission templates



According to Report ITU-R M.2411 "Requirements, Evaluation criteria, and submission templates for the development of IMT-2020".

3GPP provided the following submission templates and preliminary self evaluation



- 3GPP provided all necessary templates and preliminary self evaluation results towards IMT-2020 submission based on Rel-15 work.
- Preliminary evaluation shows that 3GPP 5G meets all IMT-2020 requirements.
- Independent evaluation groups are welcome to refer to these materials to prepare the evaluation activity.

Discussion: NCSR Demokritos: metrics to be taken into account?
Huawei: evaluation methods are defined in ITU-R M.2412 and we followed them
NCSR Demokritos: about service requirements?
Huawei: answer is based on SRIT and RIT
Qualcomm: if all applicable technical performance requirements are met for the test environment then performance is met (see slide 12)

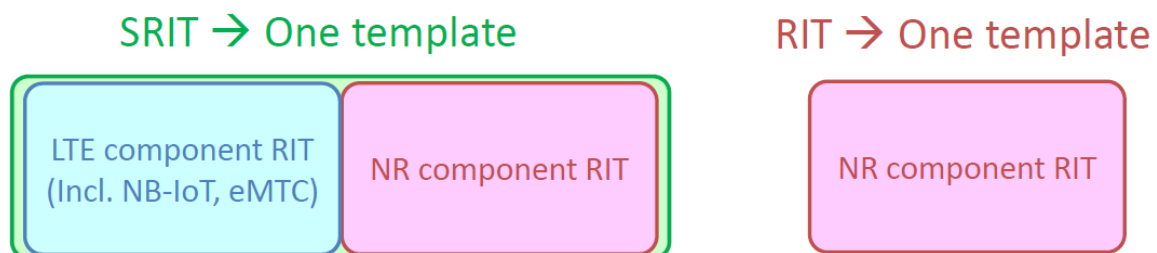
Conclusion: noted

3.2 Description characteristics template

[RWS-180015](#) [IMT-2020 submission templates: Description characteristics template](#) [NTT DOCOMO discussion](#)
presented by Mr. Kazuaki Takeda (10min+5QA)

Abstract: This document presents the overview of characteristics for SRIT and RIT of 5G. It describes new and key functionalities of NR and LTE for SRIT and RIT which are the basis for ITU evaluations.

Description characteristics templates:



Description characteristics templates will continue to be updated until the final submission

Discussion: -
Conclusion: noted

3.3 Link budget template

[RWS-180016](#) [IMT-2020 submission templates: Link budget template](#) [Ericsson](#) [discussion](#)

presented by Mr. Asbjörn Grövlén (10min+5QA)

Abstract: Presentation and explanation of the link budget template for the IMT-2020 submission, including the guideline from ITU and the assumptions made in 3GPP. Example link budgets for both NR and LTE are presented for control and data channels in UL and DL.

Link budget – what is it?

Assess the maximum supported path loss and range

- Downlink and uplink
- Data and control
- Five test environments: indoor hotspot eMBB, dense urban eMBB, rural eMBB, urban macro mMTC, urban macro URLLC

Preliminary 3GPP results provided in [RP-182097](#)

Discussion: -

Conclusion: noted

4 Self-Evaluation results (including simulation assumptions and calibration)

4.1 Calibration method and results

[RWS-180017](#) [Self-Evaluation: Calibration method and results](#) [Qualcomm](#) [discussion](#)

presented by Mr. Francesco Pica (15min+5QA)

Abstract: This presentation summarizes the activities and outcomes of the initial simulations calibration (first phase of the IMT-2020 self-evaluation study), including background/references, results and conclusions/observations.

Simulations Calibration:

- *Initial simulators calibration has been performed, for results' alignment (~20 companies contributed: CATR, CATT, CEWiT, China Telecom, China Mobile, Ericsson, Huawei, Intel, ITRI, LG Electronics, Mediatek, Motorola/Lenovo, NEC, Nokia, DOCOMO, OPPO, Qualcomm, Samsung, Sharp, vivo, ZTE)*
- *The calibration was conducted for all Test Environments and evaluation configurations (for both channel model A and B)*
- *Two metrics were selected for initial calibration: DL Geometry (SINR), Coupling gain*

Calibration phase – Timelines & Outcomes:

- *Sept. 2017 (RAN#77): Calibration phase started (over RAN ITU-R Ad-Hoc email reflector)*
- *Dec. 2017 (RAN#78): RP-172728: Initial summary of email discussion; Calibration phase extended till Feb '18*
- *Mar. 2018 (RAN/SA#79):*
 - *RP-180524: Final summary of calibration results (also captured in TR 37.910)*
 - *A Letter (SP-180248) was sent out to WP5D and all Independent Evaluation Groups (IEGs), informing about the completion of the Calibration phase (summary&results enclosed), and advertising the future 3GPP WS (Oct'18).*

Discussion: 5GPPP: any calibration planned for link level simulations from 3GPP?

Qualcomm: calibration was done for link and system level simulations, thinks no further calibration planned

Conclusion: noted

4.2 eMBB evaluation results

[RWS-180018 Self-Evaluation: eMBB evaluation results](#) [Huawei](#) [discussion](#)
presented by Mr. Yong Wu (30min)

Abstract: The preliminary self evaluation against the eMBB technical performance requirements are provided, including the evaluated features, detailed evaluation method and configurations. The evaluation will demonstrate how 3GPP 5G could fulfill and extend the capability of IMT-2020 on eMBB applications.

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 (5 th percentile user data rate)	100 Mbit/s	50 Mbit/s	-
5 th 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

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	
	5 th 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		

Discussion: 5GPPP: PRACH not considered for UL overhead calculation?

Huawei: we seek the maximum capability, once the access is established PRACH is not overhead anymore

Conclusion: noted

4.3 URLLC and mMTC evaluation results

[RWS-180019 Self-Evaluation: URLLC and mMTC evaluation results](#) [Nokia discussion](#)
presented by Mr. Karri Ranta-Aho (30min)

Abstract: This document first recaps the IMT-2020 requirements for the URLLC and mMTC. Then it summarizes the 3GPP self evaluation provided to the ITU-R as part of the 3GPP initial submission towards IMT-2020, demonstrating how the 3GPP submission fulfills these IMT-2020 requirements.

Requirements for URLLC and mMTC

Requirement	Required value
Latency, user plane	1 ms for URLLC
Latency, control plane	20 ms
Connection density	1 000 000 devices / km ²
Reliability	99.999% success rate within 1 ms
Mobility interruption time	0 ms

URLLC requirement

mMTC requirement

Large number of different configurations evaluated against the URLLC and mMTC requirements:

Requirement	Required value	NR	LTE
Latency, user plane	1 ms for URLLC	Meets requirement	Meets requirement
Latency, control plane	20 ms	Meets requirement	Meets requirement
Connection density	1 000 000 devices / km ²	Meets requirement	Meets requirement
Reliability	99.999% success rate within 1 ms	Meets requirement	Not evaluated
Mobility interruption time	0 ms	Meets requirement	Meets requirement

3GPP successfully completed the preliminary self evaluation on URLLC and mMTC

Discussion: -

Conclusion: noted

4.4 General Q&A

Questions and answers were handled together with the presentations.

5 Anticipations on the final IMT-2020 submission: Rel-16 outlook

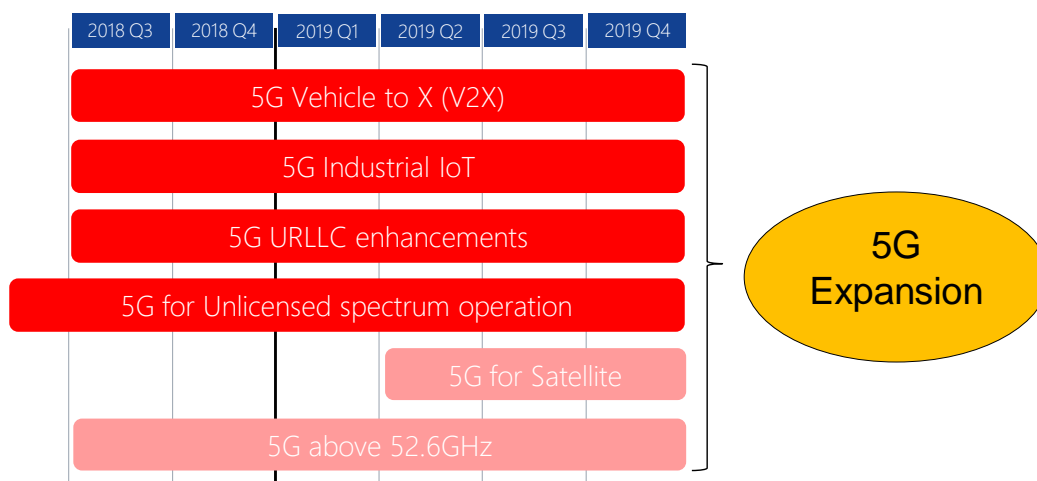
5.1 RAN aspects

RWS-180020 Anticipations on the final IMT-2020 submission: Rel-16 outlook - RAN aspects 3GPP TSG RAN chairman (Nokia) discussion

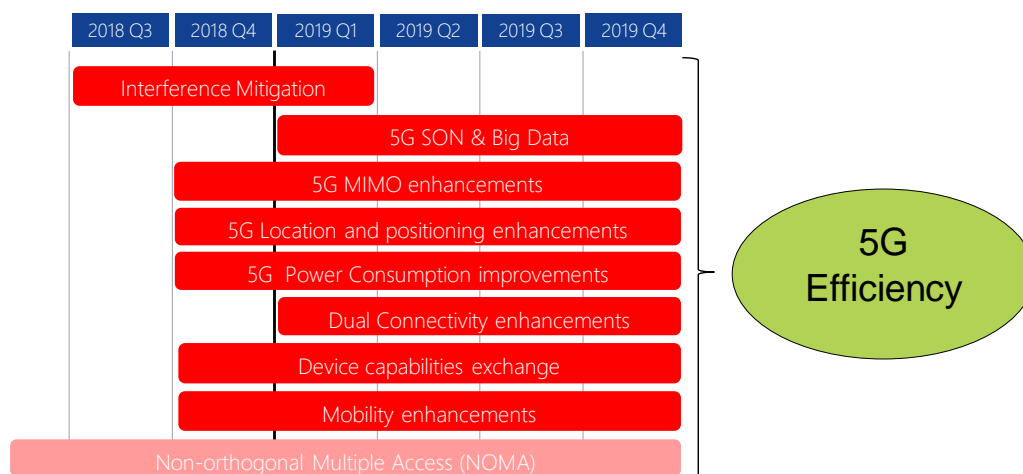
presented by Mr. Balazs Bertenyi (20min+5QA)

Abstract: After the initial 5G specification release of Release-15 3GPP is continuing the evolution of the 5G NR technology both towards better serving emerging verticals as well as better serving commercial operators. Both of these primary interests will continue to shape technology development going forward, as much as possible in harmony and balance. This presentation shows the specific features planned for 3GPP Release-16 with respect to 5G NR.

Release 16 – 5G Expansion



Release 16 – 5G Efficiency



RAN chairman:

- light red: to be seen whether normative work will be possible in Rel-16 or whether this is rather for Rel-17
- workshop planned with IEEE regarding 5G NR in unlicensed bands

Discussion: European Commission: supports that verticals should be more included, no work for broadcast and media planned
RAN chair: not in 5G NR spec, so no MBMS planned in NR
5GIA: what should verticals do to bring their ideas into 3GPP?
RAN chair (Nokia): biggest task to encourage them to create a platform where their requirements could be collected and consolidated
CT chairman (Huawei): REL-15 was practically a starting point for verticals to come to 3GPP, this will increase in the future; encourages that verticals come with their requirements to 3GPP
OnFace: page 10: UWB worked on ultra-wideband and they studied these things already
RAN chairman: location information will be derived from many different components of the mobile

Conclusion: noted

5.2 System and Core network aspects

[RWS-180021 Anticipations on the final IMT-2020 submission: Rel-16 outlook - System and Core network aspects](#)
[3GPP TSG SA chairman \(Samsung\) discussion](#)

Conclusion: revised in RWS-180022

[RWS-180022 Anticipations on the final IMT-2020 submission: Rel-16 outlook - System and Core network aspects](#)
[3GPP TSG SA chairman \(Samsung\) discussion](#)

presented by Mr. Erik, Guttman (20min+5QA)

Abstract: This presentation reviews the role of non-RAN specifications in the IMT-2020 submission. It provides an overview of some of the most significant non-RAN specifications in Release 15 and studies in Release 16.

- *Rel-16 adds 5G Vertical support: Vehicle Communication, Mission Critical Communications, Industrial Automation and Verticals, Audio Visual Production,*
- *Rel-16 also adds enhances the system: 5G LAN, High Precision Positioning, Cellular IoT for 5G, URLLC capabilities, Fixed and Satellite as 3GPP accesses, ONAP interworking, QoS Monitoring, Network Automation, protocol and core network improvements...*
- *In Rel-17 – more verticals and service enablers*
 - *logistics, e-health, unmanned aerial vehicles...*
 - *XR, ...*

Discussion: CT chairman: 2 things 2 study in CT as well: potential GTP replacement, whether/how to apply quick protocol to service based architecture

Conclusion: noted

6 Closing of the meeting

RAN chairman:

The 3GPP RAN chair thanked the presenters and participants for a very good and engaging discussions. He noted that based on all the results 3GPP officials and experts presented at the workshop there is a high level of confidence that 3GPP's submission to IMT2020 will meet the ITU requirements, and with flying colors. IEGs are encouraged to contact the relevant experts directly, with whom they have now developed direct relationships, in case any questions arise during the evaluation process.

The chairman Mr. Balazs Bertenyi, (Nokia) thanked the delegates for participating and contributing to this 3GPP workshop, he thanked the host for organizing the meeting and the cocktail event on Wednesday and he closed the meeting on Thursday 25.10.2018 at 17:00.

[RWS-180024 Draft report of the Workshop on 3GPP submission towards IMT-2020, 24-25.10.2018, Brussels, Belgium ETSI MCC Report](#)

This version was provided directly after the workshop.

In case of comments/corrections please provide them to joern.krause@etsi.org before 25.11.2018.

A final version will then be provided afterwards.

conclusion: revised in RWS-180025

[RWS-180025 Report of the Workshop on 3GPP submission towards IMT-2020, 24-25.10.2018, Brussels, Belgium ETSI MCC Report](#)

conclusion: noted?

Annex A: List of participants

The list of participants of this workshop **will be** attached to this report.

Total number of participants: **1xx** (registered before the meeting: **124**)

Annex B: List of Tdocs

Total number of Tdocs: 25 (RWS-180001 - RWS-180025) of which 24 Tdocs are available, i.e. 1 was not available and withdrawn.

TDoc	Title	Source	Type	Agenda item	Agenda item description	TDoc Status
RWS-180001	Agenda of the Workshop on 3GPP submission towards IMT-2020, held Oct. 24-25, 2018 in Brussels, Belgium	3GPP TSG RAN chairman (Nokia)	agenda	1.1	Welcome from chairman of the workshop	approved
RWS-180002	Introduction by ITU-R WP5D	ITU-R WP5D vice-chairman (Ericsson)	discussion	1.2	Welcome from ITU-R WP5D	noted
RWS-180003	Welcome from the host	Director CONNECT "Future Networks" (European Commission)	discussion	1.3	Welcome from the host	withdrawn
RWS-180004	Explanation of 3GPP submission	3GPP TSG RAN ITU-R ad hoc convener (Telecom Italia)	discussion	1.4	Explanation of 3GPP submission	noted
RWS-180005	3GPP proposal for 5G: Overview about RAN aspects	3GPP TSG RAN chairman (Nokia)	discussion	2.1.1	RAN aspects	noted
RWS-180006	System and Core Network Aspects	3GPP TSG SA chairman (Samsung)	discussion	2.1.2	System and Core network aspects	noted
RWS-180007	NR Physical layer design: Physical layer structure	3GPP TSG RAN WG1 vice-chairman (Ericsson)	discussion	2.2.1	Physical layer structure, numerology and frame structure, NR spectrum utilization mechanism	noted
RWS-180008	NR physical layer design: NR MIMO	3GPP TSG RAN WG1 vice-chairman (Samsung)	discussion	2.2.2	NR MIMO	noted
RWS-180009	NR architecture	3GPP TSG RAN WG3 chairman (Ericsson)	discussion	2.3	NR architecture	noted
RWS-180010	NR radio interface protocols	Intel	discussion	2.4	NR protocol	noted
RWS-180011	NR radio frequency and co-existence	3GPP TSG RAN WG4 chairman (Samsung)	discussion	2.5	NR radio frequency and co-existence	noted
RWS-180012	3GPP's Low-Power Wide-Area IoT Solutions: NB-IoT and eMTC	Huawei	discussion	2.6.1	NB-IoT, eMTC	noted
RWS-180013	LTE evolution	Ericsson	discussion	2.6.2	LTE evolution	noted

TDoc	Title	Source	Type	Agenda item	Agenda item description	TDoc Status
RWS-180014	IMT-2020 submission templates: Overview of 3GPP submission and compliance to IMT-2020 requirements	Huawei	discussion	3.1	Overview of 3GPP submission and compliance to IMT-2020 requirements	noted
RWS-180015	IMT-2020 submission templates: Description characteristics template	NTT DOCOMO	discussion	3.2	Description characteristics template	noted
RWS-180016	IMT-2020 submission templates: Link budget template	Ericsson	discussion	3.3	Link budget template	noted
RWS-180017	Self-Evaluation: Calibration method and results	Qualcomm	discussion	4.1	Calibration method and results	noted
RWS-180018	Self-Evaluation: eMBB evaluation results	Huawei	discussion	4.2	eMBB evaluation results	noted
RWS-180019	Self-Evaluation: URLLC and mMTC evaluation results	Nokia	discussion	4.3	URLLC and mMTC evaluation results	noted
RWS-180020	Anticipations on the final IMT-2020 submission: Rel-16 outlook - RAN aspects	3GPP TSG RAN chairman (Nokia)	discussion	5.1	RAN aspects	noted
RWS-180021	Anticipations on the final IMT-2020 submission: Rel-16 outlook - System and Core network aspects	3GPP TSG SA chairman (Samsung)	discussion	5.2	System and Core network aspects	revised
RWS-180022	Anticipations on the final IMT-2020 submission: Rel-16 outlook - System and Core network aspects	3GPP TSG SA chairman (Samsung)	discussion	5.2	System and Core network aspects	noted
RWS-180023	3GPP's Low-Power Wide-Area IoT Solutions: NB-IoT and eMTC	Huawei	discussion	2.6.1	NB-IoT, eMTC	noted
RWS-180024	Draft report of the Workshop on 3GPP submission towards IMT-2020, 24-25.10.2018, Brussels, Belgium	ETSI MCC	report	6	Closing of the meeting	revised
RWS-180025	Report of the Workshop on 3GPP submission towards IMT-2020, 24-25.10.2018, Brussels, Belgium	ETSI MCC	report	6	Closing of the meeting	

Annex C: History

Document history		
Date	Tdoc	Subject
25.10.2018	RWS-180024	Draft report provided at the end of the workshop
xx.11.2018	RWS-1800yy	Final report
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