Trans-Pacific Evaluation Group Update for IMT-2020 Evaluation

Tzu-Ming Lin
tmlin@itri.com

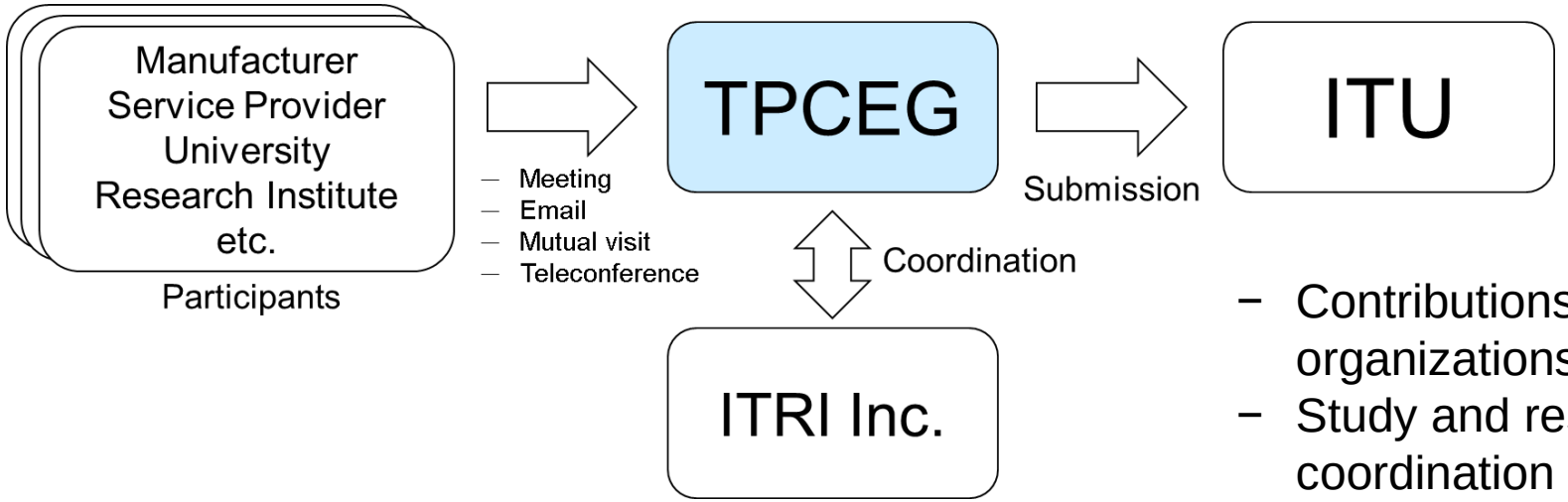
ITU-R WP 5D Workshop on
IMT-2020 Terrestrial Radio Interfaces Evaluation
Geneva, Switzerland
December 2019

Outline

- Background
  - TPCEG Overview and the Activities
  - Simulator and the Calibration
- Evaluation Detail (Simulation related)
  - Average Spectral Efficiency and Area Traffic Capacity
  - 5th Percentile User Spectral Efficiency and User Experienced Data Rate
  - Mobility
  - Connection Density
  - Reliability
- Evaluation Summary
  - LTE RIT
  - NR RIT
- Some Remarks

TPCEG Overview

- Trans-Pacific Evaluation Group (TPCEG)
  - Initialized in July 2017, and an international, nonprofit, technology-neutral study group formed by ITRI Inc.
  - Aiming to analyze and evaluate IMT-2020 (S)RIT proposals.
  - To encourage and collaborate the development of IMT-2020 industries



- Contributions are provided by participating organizations
- Study and results are discussed with the coordination of ITRI Inc.
- Evaluation results will be provided to ITU after internal harmonization

IMT-2020 Development and TPCEG

Study and evaluation results from Trans-Pacific region

ITRI
Industrial Technology Research Institute

TPCEG

RESOLUTION ITU-R 65

Resolves 6c and 6d :
ITU-R invites RIT proposals and also the related evaluations for the future development of IMT (through Resolution ITU-R 9.)

3GPP

LTE Advanced Pro

5G

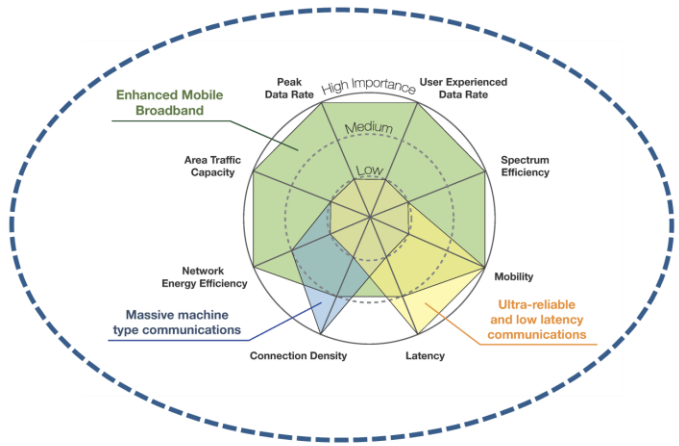
LTE + NR (+NB-IoT/eMTC)

NR only

KOREA — NR Only

CHINA — NR (+NB-IoT)

Other — RIT Combination



ITU-R
Global 5G Standard

Proponents | **IMT-2020 Proposals** | **IMT-2020 Requirements** | **IMT-2020 Specification**

TPCEG Activities

5G Infrastructure Association (5G IA)
ATIS WTSC IMT-2020 Evaluation Group (WTSC)
Chinese Evaluation Group (ChEG)
Canadian Evaluation Group (CEG)
Wireless World Research Forum (WWRF)
Telecom Centres of Excellence, India (TCOE)
TTA Special Project Group 33 (TTA SPG33)
Trans-Pacific Evaluation Group (TPCEG)
European Telecommunications Standards Institute (ETSI)
Egyptian Evaluation Group(EEG)
The Fifth Generation Mobile Communications Promotion Forum (5GMF)
5G India Forum (5GIF)
Africa Evaluation Group (AEG)

- 2017
  - ITU-R Workshop on IMT-2020 terrestrial radio interfaces, 4 October, Munich, Germany➔ **call for participation**
- 2018
  - ITU-R WP5D#31, 9th October, Fukuoka, Japan ➔ **Initial Evaluation Report**
  - 41st Meeting of the Wireless World Research Forum, 31 October, Herning, Denmark ➔**Information Sharing**
- 2019
  - 42nd Meeting of the Wireless World Research Forum, 16 May, Tokyo, Japan ➔**Global Collaboration**
  - ITU-R WP5D#33, 7th December, Geneva, Switzerland ➔ **Interim Evaluation Report**

TPCEG Proponents and Outcomes

National Cheng Kung University (NCKU)

SU-MIMO and MU-MIMO in FDD for 3GPP NR

National Chung Cheng University (NCCU)

SU-MIMO in FDD and TDD for 3GPP NR

National Taiwan University of Science and Technology (NTUST)

SU-MIMO in TDD for 3GPP NR

MU-MIMO in FDD for 3GPP NR

MediaTek Inc. (MTK)

SU-MIMO in FDD and TDD for 3GPP LTE and NR

Industrial Technology Research Institute (ITRI)

TAICS

Taiwan Association of Information and Communication Standards

Initial Evaluation Report

2018/10

Interim Evaluation Report

2019/12

Final Evaluation Report

2020/02

Evaluation Tool: WiSE, the 5G Simulator

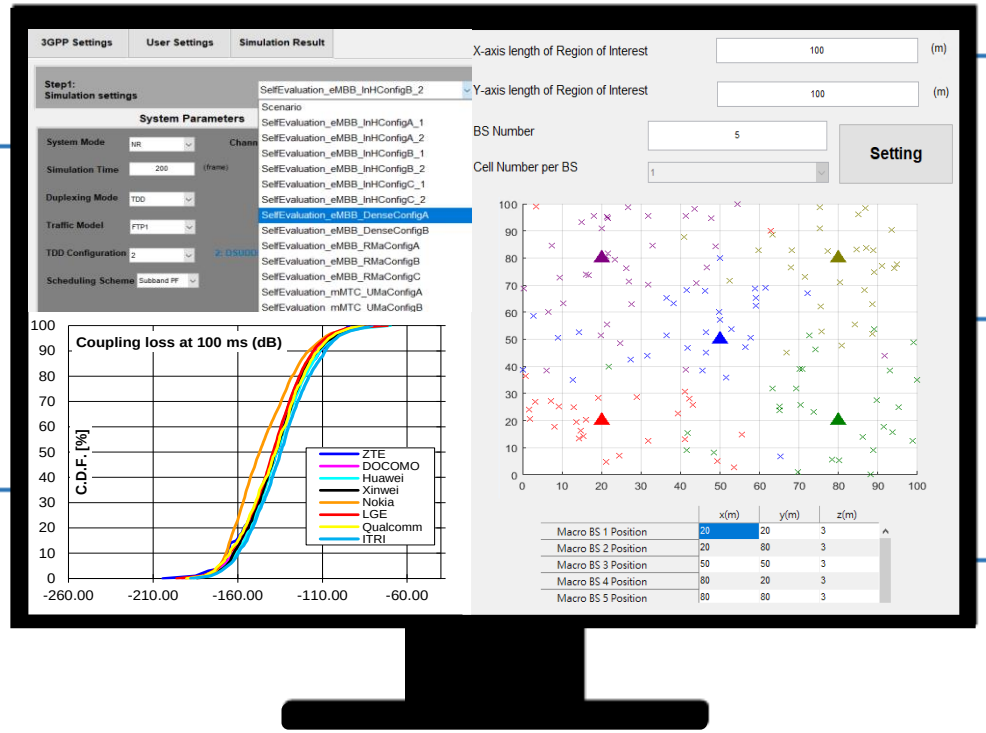
Wireless Simulator Evolution

High-frequency Channel Effects

Blockage effects、UE rotation effect、Oxygen absorption effect、Spatial consistency

Antenna Model

Cross-polarized antenna model、Multi-panel antenna array、Back-to-back panel structure、Hybrid beamforming



Network Topology

3GPP macro cells、small cell、indoor hotspot deployment

ITU-R 3D Channel Model

Indoor Hotspot、Urban Macro、Urban Micro、Rural Macro

MIMO

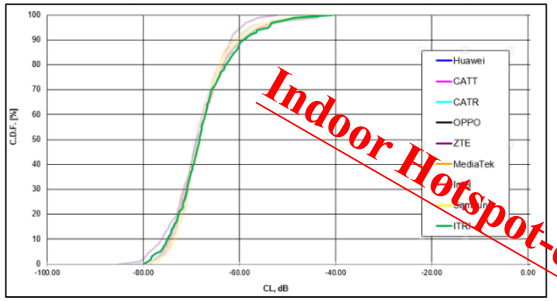
Beam Sweeping、Hybrid Beamforming、Multi-Panel Antenna Array

C. K. Jao, C. Y. Wang, T. Y. Yeh, C. C. Tsai, L. C. Lo, J. H. Chen, W. C. Pao, W. H. Sheen, "WiSE: A System-Level Simulator for 5G Mobile Networks," IEEE Wireless Communications, vol. 25, no. 2, pp. 4-7, Apr. 2018

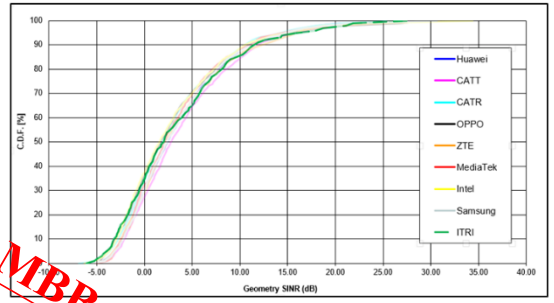
Simulator Calibration

WiSE simulator has been calibrated via *Self evaluation calibration* and the results are well aligned with other 3GPP companies.

Indoor Hotspot (12 TRPs) ModelA – Coupling Loss

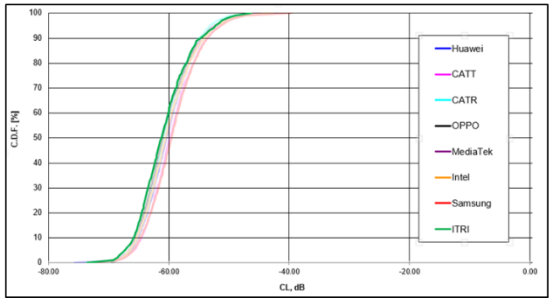


Indoor Hotspot (12 TRPs) ModelA – SINR

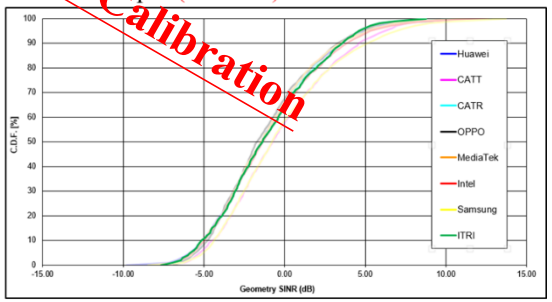


Indoor Hotspot-eMBB Calibration

Indoor Hotspot (36 TRPs) Model A – Coupling Loss

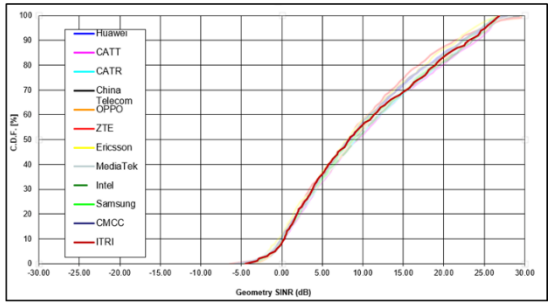


Indoor Hotspot (36 TRPs) ModelA – SINR



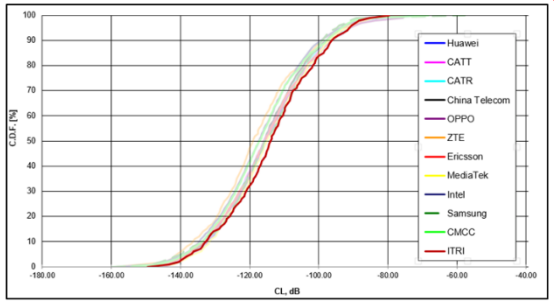
Rural ConfigA Model A – Coupling Loss

Rural Config A Model A – SINR

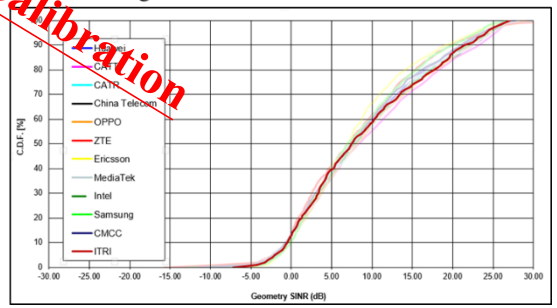


Rural-eMBB Calibration

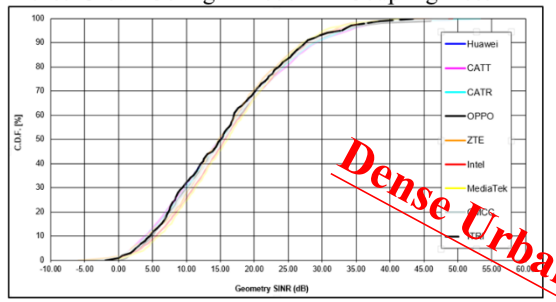
Rural Config B Model A – Coupling Loss



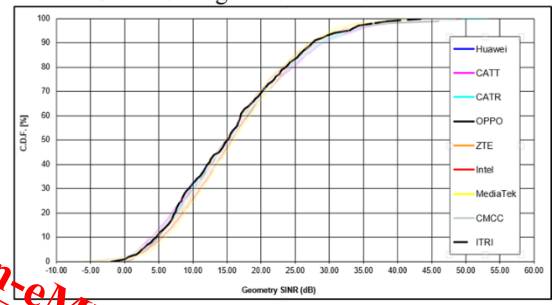
Rural Config B Model A – SINR



Dense Urban ConfigA ModelA – Coupling Loss

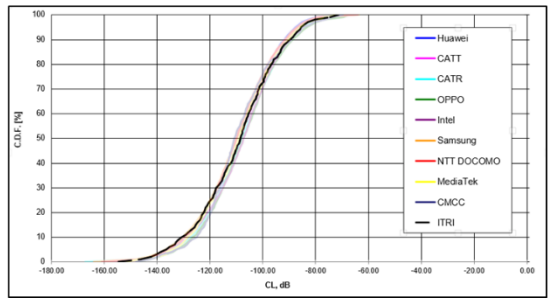


Dense Urban ConfigA ModelA – SINR

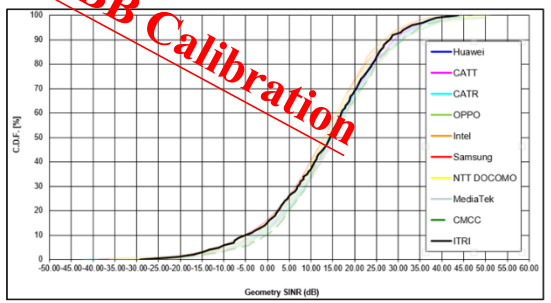


Dense Urban-eMBB Calibration

Dense Urban ConfigB – Coupling Loss



Dense Urban ConfigB – SINR



EVALUATION DETAIL (SIMULATION RELATED)

Response for WP5D Questionnaire

IMT-2020 SUBMISSION							
Registered Independent Evaluation Group	3GPP		CHINA	KOREA	TSDSI	ETSI, DECT FORUM	Nufront
	RIT	SRIT					
	IMT-2020/yy1	IMT-2020/yy2	IMT-2020/yy3	IMT-2020/yy4	IMT-2020/yy5	IMT-2020/yy6	IMT-2020/yy6
5G Infrastructure Association							
ATIS WTSC IMT-2020							
ChEG							
Canadian Evaluation Group							
Wireless World Research Forum							
Telecom Centres of Excellence, India							
The Fifth Generation Mobile Communications Promotion Forum, Japan							
TTA 5G Technology Evaluation Special Project Group							
Trans-Pacific Evaluation Group	Evaluated	Evaluated	Partial	Partial	Partial	Partial	
ETSI							
Egyptian Evaluation Group							
5G India Forum							
Africa Evaluation Group							

Average Spectral Efficiency and Area Traffic Capacity

ITU-R M.2410 (Requirement)

	Average Spectral Efficiency →	Area Traffic Capacity
Definition	Aggregate throughput of all users divided by the channel bandwidth of a specific band divided by the number of TRxPs	The total traffic throughput served per geographic area
Value	Test environment / Downlink / Uplink Indoor Hotspot – eMBB: 9 / 6.75 Dense Urban – eMBB: 7.8 / 5.4 Rural – eMBB: 3.3 / 1.6	Test environment / Downlink / Uplink Indoor Hotspot – eMBB Dense Urban – eMBB* Rural – eMBB 10 Mbit/s/m^2 / N/A
Note	– uplink/downlink ratio shall be considered as normalized effective bandwidth – Rural-eMBB LMLC (low mobility large cell) is ALSO applicable, i.e. 6000m ISD	– The same condition as Average spectral efficiency – For Indoor Hotspot only – the results can be summed in Multiple Bands cases
Method	Simulation	Analysis: Single Band / Multi-Band
		$C_{area} = \rho \times W \times SE_{avg}$ / Be summed over the bands
		C_{area} : area traffic capacity ρ : TRxP density (TRxP/m^2) SE_{avg}: average S.E. W : channel bandwidth

Average Spectral Efficiency

Indoor

Downlink

TPCEG

	Average Spectral Efficiency		3GPP LTE	3GPP NR	LTE FDD	LTE TDD	NR FDD	NR TDD
A	9	[bit/s/Hz/TRxP]	9.25~11.88	8.77~16.88	7.72737	8.55324	10.22126	11.86924
B	9	[bit/s/Hz/TRxP]	N/A	8.5~19.91	N/A	N/A	9.75989	13.5875
C	9	[bit/s/Hz/TRxP]	N/A	N/A	N/A	N/A	13.3116	15.45696

Uplink

TPCEG

	Average Spectral Efficiency		3GPP LTE	3GPP NR	LTE FDD	LTE TDD	NR FDD	NR TDD
A	6.75	[bit/s/Hz/TRxP]	7.37~8.84	6.95~15.17	6.91698	6.3177	8.2856	8.0381
B	6.75	[bit/s/Hz/TRxP]	N/A	6.9~11.44	N/A	N/A	8.3521	9.0208
C	6.75	[bit/s/Hz/TRxP]	N/A	N/A	N/A	N/A	121125	10.0995

Dense Urban

Downlink

	Average Spectral Efficiency		3GPP LTE	3GPP NR	LTE FDD	LTE TDD	NR FDD	NR TDD
A	7.8	[bit/s/Hz/TRxP]	8.78~14.91	7.87~22.33	8.94097	10.564	12.0386	15.5051
B	7.8	[bit/s/Hz/TRxP]	N/A	7.87~22.33	N/A	N/A	8.9373	11.2766

Uplink

	Average Spectral Efficiency		3GPP LTE	3GPP NR	LTE FDD	LTE TDD	NR FDD	NR TDD
A	5.4	[bit/s/Hz/TRxP]	6.59~7.68	5.51~22.48	9.53707	9.76821	9.0024	9.8796
B	5.4	[bit/s/Hz/TRxP]	N/A	5.51~22.48	N/A	N/A	6.3113	6.8697

Rural

Downlink

	Average Spectral Efficiency		3GPP LTE	3GPP NR	LTE FDD	LTE TDD	NR FDD	NR TDD
A	3.3	[bit/s/Hz/TRxP]	4.51~11.22	5.04~17.37	10.4004	11.5833	8.5608	11.8722
B	3.3	[bit/s/Hz/TRxP]	9.63~14.75	5.96~21.11	10.0495	10.838	14.4082	15.6503
C	3.3	[bit/s/Hz/TRxP]	5.96~6.86	3.9~19.29	10.0217	10.9934	11.1366	14.3415

Uplink

	Average Spectral Efficiency		3GPP LTE	3GPP NR	LTE FDD	LTE TDD	NR FDD	NR TDD
A	1.6	[bit/s/Hz/TRxP]	3.59~4.30	3.75~15.55	9.3021	9.80635	8.2938	8.8464
B	1.6	[bit/s/Hz/TRxP]	10.5	2.7~21.3	10.2188	10.4111	11.6694	10.7776
C	1.6	[bit/s/Hz/TRxP]	6.31~3.36	3.31~10.59	5.4062	5.6875	5.5601	5.9071

Area Traffic Capacity

TPCEG

Area Traffic Capacity		3GPP LTE	3GPP NR	LTE FDD	LTE TDD	NR FDD	NR TDD
10	[Mbits/s/m2]	10.2	10~15.04	(200~710MHz)	(250~830MHz)	(150~660MHz)	(170~640MHz)

Indoor, CFG A, Downlink

Area Traffic Capacity		3GPP LTE	3GPP NR	LTE FDD	LTE TDD	NR FDD	NR TDD
10	[Mbits/s/m2]	-	-	-	-	(190~600MHz)	(180~500MHz)

Indoor, CFG B, Downlink

Area Traffic Capacity		3GPP LTE	3GPP NR	LTE FDD	LTE TDD	NR FDD	NR TDD
10	[Mbits/s/m2]	-	-	-	-	(330~430MHz)	(130~580MHz)

Indoor, CFG C, Downlink

5th Percentile User Spectral Efficiency User Experienced Data Rate

<table>
<tr><th colspan="4">ITU-R M.2410 (Requirement)</th></tr>
<tr><td rowspan="2">Definition</td><td colspan="2">5th Percentile User Spectral Efficiency</td><td>➔ User Experienced Data Rate</td></tr>
<tr><td colspan="2">The 5% point of the CDF of the normalized user throughput</td><td>the 5% point of the cumulative distribution function (CDF) of the user throughput</td></tr>
<tr><td>Value</td><td colspan="2"><table><tr><th>Test environment</th><th>Downlink</th><th>Uplink</th></tr><tr><td>Indoor Hotspot – eMBB</td><td>0.3</td><td>0.21</td></tr><tr><td>Dense Urban – eMBB</td><td>0.225</td><td>0.15</td></tr><tr><td>Rural – eMBB</td><td>0.12</td><td>0.045</td></tr></table></td><td><table><tr><th>Test environment</th><th>Downlink</th><th>Uplink</th></tr><tr><td>Indoor Hotspot – eMBB</td><td rowspan="3">100 Mbit/s</td><td rowspan="3">50 Mbit/s</td></tr><tr><td>Dense Urban – eMBB</td></tr><tr><td>Rural – eMBB</td></tr></table></td></tr>
<tr><td>Note</td><td colspan="2">– The normalized user throughput is defined as the number of correctly received bits, i.e. SDU for L3, divided by the channel bandwidth.
– uplink/downlink ratio shall be considered as normalized effective bandwidth
– Rural-eMBB LMLC (low mobility large cell) is NOT applicable</td><td>– The same condition as 5th Percentile User spectral efficiency
– For Dense Urban only
– the results can be summed in Multiple Bands cases</td></tr>
<tr><td rowspan="4">Method</td><td colspan="2">Simulation</td><td colspan="2">Analysis</td></tr>
<tr><td colspan="2"></td><td>Single Band</td><td>Multi-Band</td></tr>
<tr><td colspan="2"></td><td>$R_{user} = W \times SE_{user}$</td><td>Be summed over the bands</td></tr>
<tr><td colspan="2"></td><td>R_{user} : user experienced data rate
W : channel bandwidth
SE_{user} : the 5th percentile user S.E.</td><td></td></tr>
</table>

5th Percentile User Spectral Efficiency

Indoor

Downlink

TPCEG

	5th User Spectral Efficiency		3GPP LTE	3GPP NR	LTE FDD	LTE TDD	NR FDD	NR TDD
A	0.3	[bit/s/Hz]	0.33~0.42	0.31~0.59	0.2458175	0.2746205	0.4150	0.3973
B	0.3	[bit/s/Hz]	N/A	0.31~1.18	N/A	N/A	0.3565	0.6023
C	0.3	[bit/s/Hz]	N/A	N/A	N/A	N/A	0.4318	0.7327

Uplink

TPCEG

	5th User Spectral Efficiency		3GPP LTE	3GPP NR	LTE FDD	LTE TDD	NR FDD	NR TDD
A	0.21	[bit/s/Hz]	0.32~0.54	0.27~0.63	0.231819	0.201329	0.3710	0.27217
B	0.21	[bit/s/Hz]	N/A	0.30~0.43	N/A	N/A	0.3024	0.3148
C	0.21	[bit/s/Hz]	N/A	N/A	N/A	N/A	0.3682	0.3504

Dense Urban

Downlink

	5th User Spectral Efficiency		3GPP LTE	3GPP NR	LTE FDD	LTE TDD	NR FDD	NR TDD
A	0.225	[bit/s/Hz]	0.25~0.52	0.23~0.81	0.230709	0.302268	0.4385	0.4380
B	0.225	[bit/s/Hz]	N/A	0.23~0.81	N/A	N/A	-	0.0346

(100% low-loss penetration and/or with Admission Control)

(20% high loss, 80% low loss)

Uplink

	5th User Spectral Efficiency		3GPP LTE	3GPP NR	LTE FDD	LTE TDD	NR FDD	NR TDD
A	0.15	[bit/s/Hz]	0.3~0.41	0.16~0.60	0.350235	0.347855	0.4569	0.3573
B	0.15	[bit/s/Hz]	N/A	0.23~0.81	N/A	N/A	-	0.0188

(100% low-loss penetration and/or with Admission Control)

(20% high loss, 80% low loss)

Rural

Downlink

	5th User Spectral Efficiency		3GPP LTE	3GPP NR	LTE FDD	LTE TDD	NR FDD	NR TDD
A	0.12	[bit/s/Hz]	0.25~0.52	0.23~0.81	0.275462	0.323954	0.4223	0.3116
B	0.12	[bit/s/Hz]	0.28~0.46	0.12~2.11	0.292282	0.3256528	0.4771	0.4263
C	-	[bit/s/Hz]	N/A	N/A	0.275619	0.330157	0.4464	0.3627

Uplink

	5th User Spectral Efficiency		3GPP LTE	3GPP NR	LTE FDD	LTE TDD	NR FDD	NR TDD
A	0.045	[bit/s/Hz]	0.3~0.41	0.16~0.60	0.290422	0.305628	0.3984	0.1377
B	0.045	[bit/s/Hz]	0.07	0.12~0.71	0.176055	0.15916	0.3317	0.1359
C	-	[bit/s/Hz]	N/A	N/A	0.231291	0.252252	0.3671	0.1986

User Experienced Data Rate

TPCEG

User Experienced Data Rate		3GPP LTE	3GPP NR	LTE FDD	LTE TDD	NR FDD	NR TDD
100	[Mbits/s]	100.19~105.43	100.87~149.29	(440MHz)	(440MHz)	(200~220MHz)	(290~320MHz)

Dense Urban, CFG A, Downlink

User Experienced Data Rate		3GPP LTE	3GPP NR	LTE FDD	LTE TDD	NR FDD	NR TDD
50	[Mbits/s]	50.83~65.12	50.06~73.15	(150MHz)	(600MHz)	(110~180MHz)	(530~690MHz)

Dense Urban, CFG A, Uplink

User Experienced Data Rate		3GPP LTE	3GPP NR	LTE FDD	LTE TDD	NR FDD	NR TDD
100	[Mbits/s]	-	-	-	-	(350~360MHz)	(3140~5120MHz)

Dense Urban, CFG B, Downlink

User Experienced Data Rate		3GPP LTE	3GPP NR	LTE FDD	LTE TDD	NR FDD	NR TDD
50	[Mbits/s]	-	-	-	-	(180~190MHz)	(8140~13270MHz)

Dense Urban, CFG B, Uplink

Mobility

Usage Scenario	Test Environment
eMBB	Indoor Spot, Dense Urban, Rural

TU-R M.2410 (Requirement)

Definition	The maximum mobile station speed at which a defined QoS can be achieved
Requirement	See table below

Test environment	Normalized traffic channel link data rate (Bit/s/Hz)	Mobility (km/h)
Indoor Hotspot – eMBB	1.5	10
Dense Urban – eMBB	1.12	30
Rural – eMBB	0.8	120
	0.45	500

- Mobility Classes (maximum speed)
  - Stationary: 0 km/h
  - Pedestrian: 0 km/h to 10 km/h
  - Vehicular: 10 km/h to 120 km/h
  - High speed vehicular: 120 km/h to 500 km/h

Evaluation Configuration

700 MHz	4 GHz	30 GHz
200, 1732m (ISD)	200m (ISD)	200m (ISD)
Configuration : depending on speeds		
Mobility : 10, 30, 120, 500 km/h for indoor and outdoor		

ITU-R M.2412 (Evaluation)

Simulation

SLS followed by LLS

1. Run uplink SLS and find 5th percentile user spectral efficiency for speeds listed in the table, and collect uplink SINR values using LLS over values for each test environment.
2. Use the CDF to save 50th percentile SINR value.
3. Run uplink LLS to obtain link data rate and residual packet error rate as a function of SINR.
4. Compare the uplink spectral efficiency with corresponding threshold values.
5. The proposal fulfills the requirement if the spectral efficiency value is larger than the threshold value under the condition of decoded packet error rate less than 1%.

Mobility

Indoor, CFG A, 4GHz

TPCEG

Requirement		3GPP LTE	3GPP NR	TXRU mapping	Tx scheme	Numerology	Duplexing	ITRI -NR	
		NLOS/LOS	NLOS/LOS					NLOS	LOS
Mobility Traffic Channel Data Rate [bits/s/Hz]	1.5 (10km/h)	1.9~2.6*	1.78~1.97	gNB: 8R = (4,4,2,1,1;,1,4) UE: 1T = (1,1,1,1,1;1,1)	1 X 8 SU-MIMO	15kHz	FDD	1.0450757	0.3871

Dense Urban, CFG A, 4GHz

Mobility Traffic Channel Data Rate [bits/s/Hz]	1.12 (30km/h)	1.81~1.99	1.97~2.19	gNB: 8R = (8,4,2,1,1;1,4) UE: 1T = (1,1,1,1,1;1,1)	1 X 8 SU-MIMO	15kHz	FDD	1.1312	1.312

Rural, CFG A, 700MHz

Mobility Traffic Channel Data Rate [bits/s/Hz]	0.8 (120km/h)	2.20~2.79	1,71~2.49	gNB: 4R = (8,2,2,1,1;1,2) UE: 1T = (1,1,1,1,1;1,1)	1 X 4 SU-MIMO	15kHz	FDD	0.85063	0.90163
	0.45 (500km/h)	1.94~2.59	1.53~2.53			30kHz		0.8501	0.88531

Rural, CFG B, 4GHz

Mobility Traffic Channel Data Rate [bits/s/Hz]	0.8 (120km/h)	N/A	1.56~2.08	gNB: 4R = (8,2,2,1,1;1,2) UE: 1T = (1,1,1,1,1;1,1)	1 X 4 SU-MIMO	30kHz	FDD	1.045039	0.7874
	0.45 (500km/h)	N/A	0.91~1.35			60kHz		0.192	

Connection Density

Usage Scenario	Test Environment
mMTC	Urban Macro-mMTC

ITU-R M.2410 (Requirement)		
Definition	total number of devices fulfilling a specific quality of service (QoS) per unit area (per km^2)	
Requirement	1,000 ,000	devices/km^2
— Should be achieved for a limited bandwidth and number of TRxPs — The target QoS is to support delivery of a message of a certain size within a certain time and with a certain success probability		

Evaluation Configuration (700MHz)	
Configuration A	Configuration B
500m (ISD)	1732m (ISD)
10 MHz Bandwidth	50MHz Bandwidth
32 bytes at layer 2 PDU	
1 message/day/device or 1 message 2 hours/device[1]	
Deployment : 80% indoor, 20% outdoor	
Mobility : 3 km/h for indoor and outdoor	

ITU-R M.2412 (Evaluation)	
Simulation	
Method 1	Method 2
non-full buffer SLS	full-buffer SLS, followed by LLS
1. Set number N for TRxPs 2. Generate packets 3. Run SLS for packet outage rate (delay < 10 sec.) 4. Change N and repeat until N' satisfying the packet outage rate of 1 % 5. Calculate connection density C with N' and Area ($A=ISD^2 \times \sqrt{3} / 6$)	1. Perform SLS with parameters to determine SINRi for each percent tile of users (i=1…99) 2. Perform LLS to determine user data rate Ri 3. Calculate packet transmission delay for users as Di = S/Ri 4. Calculate the traffic generated per user as $T = S/T_{inter\text{-}arrival}$ 5. Calculate requested resource under SINRi as Bi = T/(Ri/Wi) 6. Calculate the number of supported connections per TRxP, N = W/mean(Bi) 7. Calculate connection density C with N and Area ($A=ISD^2 \times \sqrt{3} / 6$)

Connection Density

Configuration A, 500m ISD, Downlink

TPCEG

Requirement		3GPP LTE	3GPP NR
Connection Density [device/km2]	1,000,000	34,884,438~ 43,691,789	36,007,832~ 36,323,844

TXRU mapping	Tx scheme	Numerology	Duplexing	Traffic	ITRI-LTE	ITRI-NR
gNB: 2R = (8,1,2,1,1; 1,1) UE: 1T=1T, (1,1,1,1,1; 1,1)	1x8 SU-MIMO	15kHz, SCS	FDD	1 message/2 hours/device	41,144,272	40,154,329
gNB: 2R = (8,1,2,1,1; 1,1) UE: 1T=1T, (1,1,1,1,1; 1,1)	1x8 SU-MIMO	15kHz SCS	FDD	1 message/day/device	493,731,267	481,851,947

Configuration B, 1732m ISD, Downlink

Requirement		3GPP LTE	3GPP NR
Connection Density [device/km2]	1,000,000	1,212,909~ 2,335,319	1,267,406~ 1,503,394

TXRU mapping	Tx scheme	Numerology	Duplexing	Traffic	ITRI-LTE	ITRI-NR
gNB: 2R = (8,1,2,1,1; 1,1) UE: 1T=1T, (1,1,1,1,1; 1,1)	1x8 SU-MIMO	15kHz, SCS	FDD	1 message/2 hours/device	1,404,697	1,746,033
gNB: 2R = (8,1,2,1,1; 1,1) UE: 1T=1T, (1,1,1,1,1; 1,1)	1x8 SU-MIMO	15kHz SCS	FDD	1 message/day/device	16,856,369.00	20,952,390

Reliability

Usage Scenario	Test Environment
uRLLC	Urban Macro-uRLLC

ITU-R M.2410 (Requirement)		
Definition	The capability of transmitting a given amount of traffic within predetermined time duration with high success probability.	
Requirement	$1\text{-}10^{-5}$	success probability

— From ingress point to L2/3 SDU egress point at a certain channel quality.
— Small application data (e.g. 20 bytes application data + protocol overhead).

Evaluation Configuration	
Configuration A	Configuration B
4 GHz	700 MHz
Up to 100 MHz Bandwidth	Up to 40 MHz Bandwidth
L2 PDU of 32 bytes within 1 ms	
Deployment : 80% indoor, 20% outdoor	
3 km/h for indoor and 30 km/h for outdoor	

ITU-R M.2412 (Evaluation)

Simulation

SLS followed by LLS

1. Run SLS for downlink and uplink using the evaluation parameters of Urban Macro-URLLC test environment.
2. Use the CDF result to save the respective 5th percentile downlink or uplink SINR value.
3. Run LLS to obtain success probability, which equals to (1-Pe), where Pe is the residual packet error ratio within maximum delay time as a function of SINR taking into account retransmission.
4. Check the proposal fulfils the reliability requirement if at the 5^{th} percentile downlink or uplink *SINR* value of *Step 2* and within the required delay, the success probability derived in *Step 3* is larger than or equal to the required success probability

Reliability

TPCEG

Configuration A, 4GHz

Requirement		3GPP LTE	3GPP NR	TXRU mapping	Tx scheme	Numerology	Duplexing	ITRI-LTE	ITRI-NR	
Reliabilty	99.9999%			gNB: 8T = (8,4,2,1,1;1,4) UE: 4R=(1,2,2,1,1;1,2)	8x4 SU-MIMO	15kHz, SCS	FDD		99.99929997%	Downlink
			> 99.9999%	Various	Various					

Requirement		3GPP LTE	3GPP NR	TXRU mapping	Tx scheme	Numerology	Duplexing	ITRI-LTE	ITRI-NR	
Reliabilty	99.9999%			gNB: 8R = (8,4,2,1,1;1,4) UE: 1T=(1,1,2,1,1;1,1)	1x8 SU-MIMO	15kHz, SCS	FDD		99.99999%	Uplink
			> 99.9999%	Various	Various					
			99.999991%	gNB: 64R = (12,8,2,1,1; 4,8) UE: 2T=(1,1,2,1,1; 1,1)			TDD			

Configuration B, 700MHz

Requirement		3GPP LTE	3GPP NR	TXRU mapping	Tx scheme	Numerology	Duplexing	ITRI-LTE	ITRI-NR	
Reliabilty	99.9999%			gNB: 2Tx (8,1,2,1,1;1,1) UE: 2Rx (1,1,2,1,1;1,1)	2x2 SU-MIMO	15kHz, SCS	FDD		99.999299998%	Downlink
			> 99.9999%	Various	Various					

Requirement		3GPP LTE	3GPP NR	TXRU mapping	Tx scheme	Numerology	Duplexing	ITRI-LTE	ITRI-NR	
Reliabilty	99.9999%			gNB: 8R = (8,1,2,1,1;1,4) UE: 1T=(1,1,1,1,1;1,1)	1x8 SU-MIMO	15kHz, SCS	FDD		99.999999984%	Uplink
			> 99.9999%	Various	Various					
			0.999999958	gNB: 64R = (12,8,2,1,1; 4,8) UE: 2T=(1,1,2,1,1; 1,1)			TDD			

EVALUATION SUMMARY

Evaluation Summary – LTE RIT

	Performance Metrics	Requirements (downlink / uplink)	
1	Peak Data Rate	20 / 10	Gbit/s
2	Peak spectral efficiency	30 / 15	bit/s/Hz
3	User Experienced Data Rate	100 / 50	Mbit/s
4	5th percentile user spectral efficiency	0.3/0.21, 0.225/0.15, 0.12/0.045	bit/s/Hz/TRxP
5	Average spectral efficiency	9/6.75, 7.8/5.4, 3.3/1.6	bit/s/Hz/TRxP
6	Area Traffic Capacity	10 (InH)	Mbit/s/m^2
7	Energy efficiency	Inspection	
8	Mobility	1.5 (10km), 1.12(30km), 0.8(120km), 0.45(500km)	bit/s/Hz
9	User plane latency	4 (eMBB), 1(uRLLC)	ms
10	Control plane latency	20	ms
11	Mobility interruption time	0	ms
12	Reliability	1-10^{-5}	
13	Connection density	1,000,000	Devices/km^2

Meet requirement?

LTE with NB-IoT

eMBB, InH			eMBB, DeU		eMBB, RuI			mMTC UrM	uRLLC UrM	Check?
CFG A	CFG B	CFG C	CFG A	CFG B	CFG A	CFG B	CFG C			
21.568~28.4 / 2.688~13.5872										◎
43.2920~44.38 / 17.8426~21.2308										◎
			note	note						◎
0.19~0.34/ 0.19~0.25	-	-	0.23~0.3/ 0.36~0.49	-	0.27~0.32 / 0.29~0.3	0.29~0.32/ 0.15~0.17	0.27~0.33/ 0.23~0.25			◎
7~9.12/ 6.12~7.17	-	-	8.94~14.23/ 6.4~11.72	7.9~16.7/ 5.7~7.5	10.4~11.5 / 9.3~9.8	10~10.8 / 10.2~10.4	10~10.0 / 5.4~5.6			◎
note	-	-								◎
										T.B.D.
										T.B.D.
										T.B.D.
										T.B.D.
										T.B.D.
								>		
								[◎]		

Note : with sufficient bandwidth

Evaluation Summary – NR RIT

	Performance Metrics	Requirements (downlink / uplink)	
1	Peak Data Rate	20 / 10	Gbit/s
2	Peak spectral efficiency	30 / 15	bit/s/Hz
3	User Experienced Data Rate	100 / 50	Mbit/s
4	5th percentile user spectral efficiency	0.3/0.21, 0.225/0.15, 0.12/0.045	bit/s/Hz/TRxP
5	Average spectral efficiency	9/6.75, 7.8/5.4, 3.3/1.6	bit/s/Hz/TRxP
6	Area Traffic Capacity	10 (InH)	Mbit/s/m^2
7	Energy efficiency	Inspection	
8	Mobility	1.5 (10km), 1.12(30km), 0.8(120km), 0.45(500km)	bit/s/Hz
9	User plane latency	4 (eMBB), 1(uRLLC)	ms
10	Control plane latency	20	ms
11	Mobility interruption time	0	ms
12	Reliability	1-10^{-5}	
13	Connection density	1,000,000	Devices/km^2

Meet requirement?

NR only

eMBB, InH			eMBB, DeU		eMBB, RuI			mMTC UrM	uRLLC UrM	Check?
CFG A	CFG B	CFG C	CFG A	CFG B	CFG A	CFG B	CFG C			
38.42~174.76 / 4.27~40.5										◎
31.8~48.6 / 20.0~25.03										◎
			note	note						◎
0.31~0.48 / 0.19~0.48	0.4~0.78 / 0.19~0.4	0.39~0.84 / 0.12~0.47	0.38~0.51 / 0.29~0.49	0.02*0.04/ 0.015*0.025	0.12~0.53 / 0.07~0.55	0.41~0.53 / 0.09~0.53	0.26~0.55/ 0.09~0.46			◎
7.5~13 / 6~9.9	10.4~13.0 / 5.19~10.4	11.5~18.2 / 10.12~12.3	8.4~15.7/ 6.4~11.7	8.6~16.7/ 5.7~7.5	5~16.2/ 4.5~11.8	13.7~15.8 / 9.7~13.2	5.26~15.93/ 4~7.5			◎
note	note	note								◎
										T.B.D.
0.38~1.04			1.13~1.31		0.85~0.90/ 0.85~0.88	0.78~1.04/ 0.192				◎
										T.B.D.
										T.B.D.
										T.B.D.
									>	◎
								>		◎
F.F.S.	[◎]	[◎]	[◎]	[△]	[◎]	F.F.S.	[◎]	[◎]	[◎]	

Note : with sufficient bandwidth

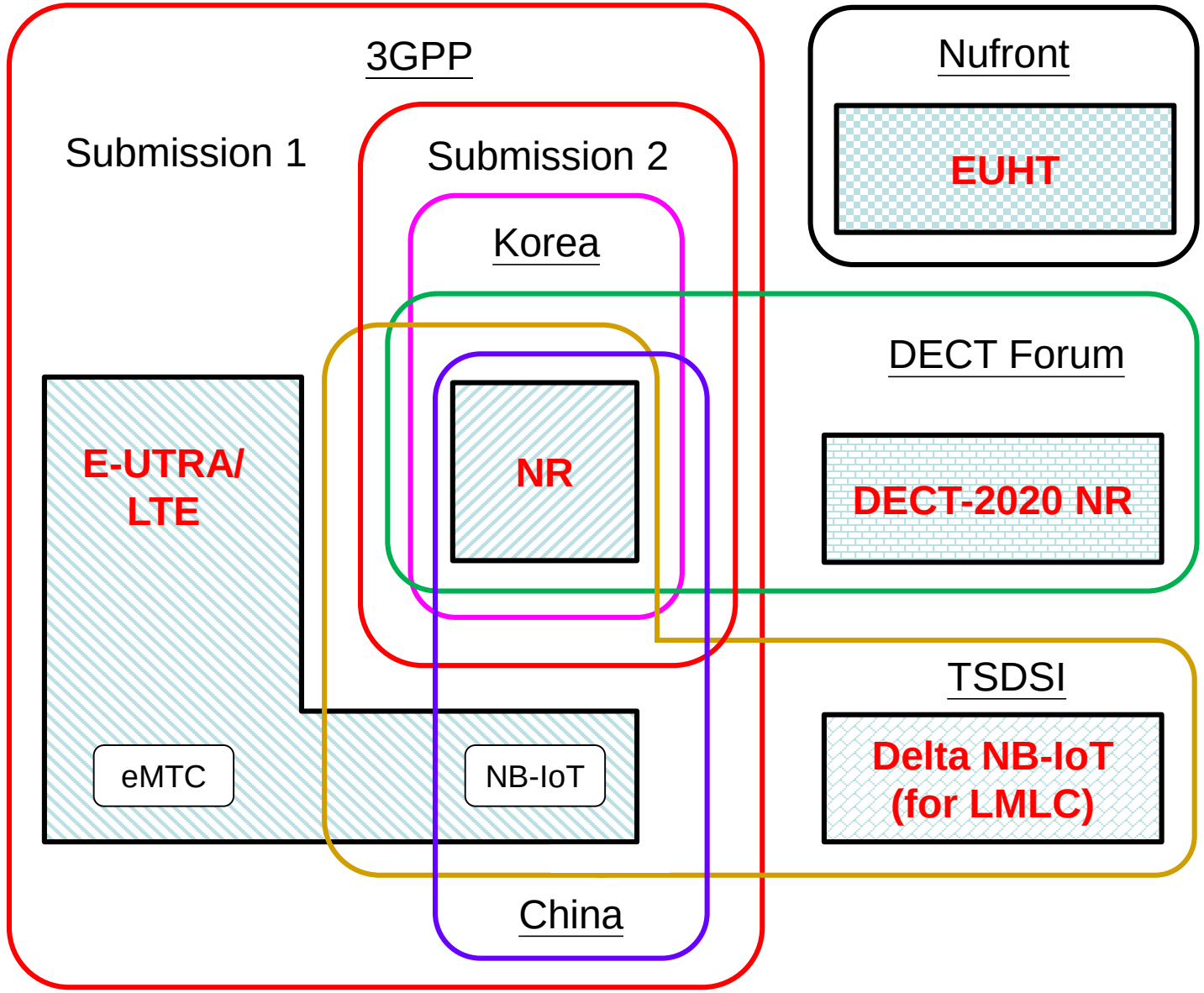
SOME REMARKS

IMT-2020 Submissions and Core Technologies

7 submissions from
6 proponents with
5 Technologies
4 submissions are
confirmed

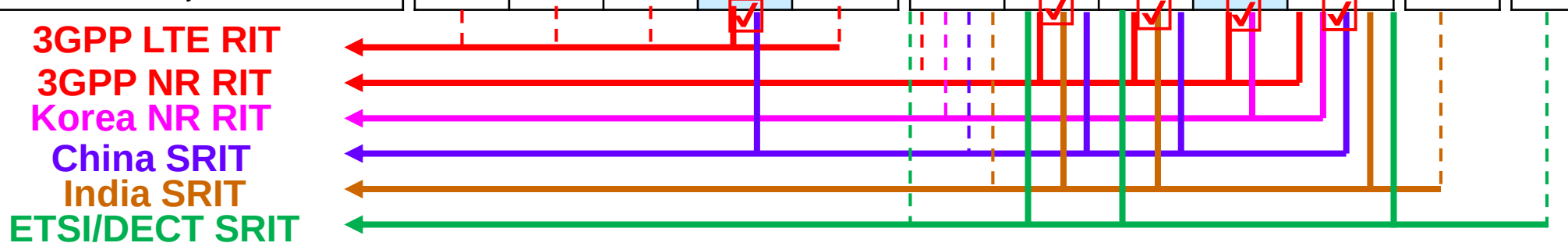
Proponent	Doc.	Subm.	RIT
3GPP	1216	SRIT	E-UTRA/LTE (3GPP)
			NR (3GPP)
	1217	RIT	NR (3GPP)
Korea	1233	RIT	NR (3GPP)
China	1268	RIT	NR + NB-IoT (3GPP)
ETSI TC DECT	1230	SRIT	DECT-2020 NR
			NR (3GPP)
TSDSI	1231	RIT	NR (3GPP) + NB-IoT'
Nufront	1238	RIT	EUHT

RIT : Radio Interface Technology
SRIT : Set of RIT
NR : New Radio
EUHT : Enhanced Ultra High Throughput



Technical View Points

	Requirements	3GPP LTE RIT with NB-IoT					3GPP NR RIT					Delta NB-IoT	DECT-2020 NR	EUHT		
		eMBB InH	eMBB DeU	eMBB Rul	mMTC UrM	uRLLC UrM	eMBB InH	eMBB DeU	eMBB Rul	mMTC UrM	uRLLC UrM	mMTC UrM	mMTC UrM	eMBB TE		uRLLC TE
1	Peak Data Rate	◎	◎	◎			◎	◎	◎							
2	Peak spectral efficiency	◎	◎	◎			◎	◎	◎							
3	User Experienced Data Rate		◎					◎								
4	5th percentile user spectral efficiency	◎	◎	◎			◎	◎/△	◎							
5	Average spectral efficiency	◎	◎	◎			◎	◎	◎							
6	Area Traffic Capacity	◎					◎									
7	Energy efficiency	◎	◎	◎			◎	◎	◎						.....	
8	Mobility						F.F.S.	◎	◎							
9	User plane latency															
10	Control plane latency															
11	Mobility interruption time															
12	Reliability										◎					
13	Connection density				◎					◎						



Nufront RIT

Related Information

- Contact person(s):
  - name: Tzu-Ming Lin
  - telephone: +14084289988
  - email: tmlin@itri.com;
  - name: Ching-Tarng Hsieh
  - telephone: +88635917397
  - email: chsieh@itri.org.tw
- Web Site : http://tpceg.org/