Evaluation of 5G NR Standard Candidates by System-Level Simulations

Communication to CEG in Presentation Format of Results Obtained as of 2019-11-14

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1. Introduction

o Research and development of signal processing algorithms for 5G NR require a realistic and flexible simulation environment.

o In this work, we use a MATLAB-based downlink/uplink physical-layer simulator for the evaluation of submitted 5G standard candidates.

o The simulator has to handle the different features proposed by each of the candidates for their realistic performance evaluation.

2. System-Level Simulation Metrics Applicability

TE	ASE [bps/Hz/TRxP]	5% USE [bps/Hz]	CD [devices/km²]	Mobility [km/h]	Reliability [%]
Indoor Hotspot-eMBB	✓	✓	N/A	✓	N/A
Dense Urban-eMBB	✓	✓	N/A	✓	N/A
Rural eMMB	✓	✓	N/A	✓	N/A
Urban Macro–mMTC	N/A	N/A	✓	N/A	N/A
Urban Macro–URLLC	N/A	N/A	N/A	N/A	✓

TE: Test environment   **ASE**: Average: spectral efficiency   **USE**: User spectral efficiency

CD: Connection density   ✓ : Applicable   N/A : Not applicable

3. Considered Candidates and Scenarios

TE	3GPP RITs	3GPP SRITs (LTE)	NuFront	ETSI SRITs (DECT)	TSDSI
Indoor Hotspot-eMBB	✓	✓	…	✓	✓
Dense Urban-eMBB	✓	✓	…	✗	✓
Rural eMMB	✓	✓	…	✗	✓
Urban Macro–mMTC	✓	✓	…	✓	✓
Urban Macro–URLLC	✓	✓	…	✓	✓

✓ : Addressed   ✗ : Not requested as per candidate's instructions

China and Korea have the same requirements as of 3GPP RITs.

4. Status of Candidates' Evaluation by CEG

TE	3GPP RITs		3GPP SRITs (LTE)	NuFront	ETSI SRITs (DECT)	TSDSI
	INRS	UofT	INRS	INRS	INRS	INRS
Indoor Hotspot-eMBB	✓ (in progress)	◌	◌	◌	◌	✓ (in progress)
Dense Urban-eMBB	✓	✓	◌	◌	✗	✓
Rural eMMB	✓	✓	◌	◌	✗	◌
Urban Macro–mMTC	✓ (in progress)	✓	◌	◌	◌	✓ (in progress)
Urban Macro–URLLC	◌	✓	◌	◌	◌	◌

✓ : Evaluated   ◌ : In progress   ✗ : Not requested

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5. Status of 3GPP Evaluation on Downlink (FDD & TDD)

TE	ASE [bps/Hz/TRxP]	5% USE [bps/Hz]	CD [devices/km²]	Mobility [km/h]	Reliability [%]
Indoor Hotspot-eMBB	⟳✓	⟳✓	✖	✖	✖
Dense Urban-eMBB	✓	✓	✖	✖	✖
Rural eMMB	✓	✓	✖	✖	✖
Urban Macro–mMTC	✖	✖	✖	✖	✖
Urban Macro–URLLC	✖	✖	✖	✖	⟳

✓ : Evaluated   ⟳ : In progress   ✖ : Not requested

6. Status of 3GPP Evaluation on Uplink (FDD & TDD)

TE	ASE [bps/Hz/TRxP]	5% USE [bps/Hz]	CD [devices/km²]	Mobility [km/h]	Reliability [%]
Indoor Hotspot-eMBB	In progress	In progress	✗	In progress	✗
Dense Urban-eMBB	✓	✓	✗	✓	✗
Rural eMMB	✓	✓	✗	In progress	✗
Urban Macro–mMTC	✗	✗	In progress	✗	✗
Urban Macro–URLLC	✗	✗	✗	✗	In progress

✓ : Evaluated   ⟳ : In progress   ✗ : Not requested

7. Results

Slides containing updated results

Color code:

: Threshold   : Pass   : Fail

7.1. Results – ASE and 5% USE (1/13)

Candidate: 3GPP						
eMBB – Indoor Hotspot (FDD)	**Configuration A (4 GHz)**					
Metric	**Link**	**M.2410**	**3GPP Min/Max**	**INRS**	**UofT**	**MEDIATEK**	**TPCEG**

Metric	Link	M.2410	3GPP Min/Max	INRS	UofT	MEDIATEK	TPCEG
ASE [bps/Hz/TRxP]	DL	9.000	8.770/16.880	10.750	…	11.120	10.544
	UL	6.750	6.950/15.170	…	…	8.820	8.588
5% USE [bps/Hz]	DL	0.300	0.310/0.590	0.331	…	0.330	0.360
	UL	0.210	0.270/0.630	…	…	0.590	0.411

7.1. Results – ASE and 5% USE (2/13)

Candidate: 3GPP						

eMBB – Indoor Hotspot (TDD)		Configuration A (4 GHz)					
Metric	**Link**	**M.2410**	**3GPP** Min/Max	**INRS**	**UofT**	**Huawei**	**CATT**
ASE [bps/Hz/TRxP]	**DL**	9.000	8.770/16.880	11.095	…	13.021	13.456
	UL	6.750	6.950/15.170	…	…	7.003	9.256
5% USE [bps/Hz]	**DL**	0.300	0.310/0.590	0.416	…	0.392	0.504
	UL	0.210	0.270/0.630	…	…	0.390	0.565

7.1. Results – ASE and 5% USE (3/13)

Candidate: 3GPP						
eMBB – Indoor Hotspot (FDD)		**Configuration B (30 GHz)**				
Metric	**Link**	**M.2410**	**3GPP Min/Max**	**INRS**	**UofT**	**MEDIATEK**	**SAMSUNG**
ASE [bps/Hz/TRxP]	DL	9.000	8.500/19.910	…	…	12.690	8.495
	UL	6.750	6.900/11.440	…	…	10.386	7.657
5% USE [bps/Hz]	DL	0.300	0.310/1.180	…	…	0.408	0.313
	UL	0.210	0.300/0.430	…	…	0.414	0.394

7.1. Results – ASE and 5% USE (4/13)

Candidate: 3GPP							

eMBB – Indoor Hotspot (TDD)		Configuration B (30 GHz)					
Metric	**Link**	**M.2410**	**3GPP Min/Max**	**INRS**	**UofT**	**Huawei**	**CATT**
ASE [bps/Hz/TRxP]	DL	9.000	8.500/19.910	17.811	…	11.599	16.745
	UL	6.750	6.900/11.440	…	…	7.037	7.440
5% USE [bps/Hz]	DL	0.300	0.310/1.180	0.610	…	0.308	0.997
	UL	0.210	0.300/0.430	…	…	0.405	0.374

7.1. Results – ASE and 5% USE (5/13)

Candidate: 3GPP							
eMBB – Dense Urban (FDD)		**Configuration A (4 GHz)**					
Metric	**Link**	**M.2410**	**3GPP Min/Max**	**INRS**	**UofT**	**MEDIATEK**	**TPCEG**
ASE [bps/Hz/TRxP]	DL	7.800	7.870/22.330	11.200	11.270	11.390	11.867
	UL	5.400	5.510/22.480	6.087	6.512	8.790	8.702
5% USE [bps/Hz]	DL	0.225	0.230/0.810	0.248	0.380	0.400	0.421
	UL	0.150	0.160/0.600	0.273	0.228	0.505	0.347

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7.1. Results – ASE and 5% USE (6/13)

Candidate: 3GPP						
eMBB – Dense Urban (TDD)	**Configuration A (4 GHz)**					
Metric	**Link**	**M.2410**	**3GPP Min/Max**	**INRS**	**UofT**	**MEDIATEK**	**TPCEG**
ASE [bps/Hz/TRxP]	DL	7.800	7.870/22.330	14.371	13.371	X	X
	UL	5.400	5.510/22.480	6.099	6.462	X	X
5% USE [bps/Hz]	DL	0.225	0.230/0.810	0.328	0.430	X	X
	UL	0.150	0.160/0.600	0.274	0.213	X	X

7.1. Results – ASE and 5% USE (7/13)

Candidate: 3GPP						

eMBB – Dense Urban (FDD)		Configuration B (30 GHz)					
Metric	**Link**	**M.2410**	**3GPP** Min/Max	**INRS**	**UofT**	**MEDIATEK**	**TPCEG**
ASE [bps/Hz/TRxP]	DL	7.800	X	13.752	11.360	X	X
	UL	5.400	X	6.087	6.397	X	X
5% USE [bps/Hz]	DL	0.225	X	0.490	0.350	X	X
	UL	0.150	X	0.244	0.264	X	X

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7.1. Results – ASE and 5% USE (8/13)

Candidate: 3GPP						

eMBB – Dense Urban (TDD)		Configuration B (30 GHz)					
Metric	**Link**	**M.2410**	**3GPP Min/Max**	**INRS**	**UofT**	**MEDIATEK**	**TPCEG**
ASE [bps/Hz/TRxP]	DL	7.800	X	13.521	13.144	X	X
	UL	5.400	X	5.994	7.752	X	X
5% USE [bps/Hz]	DL	0.225	X	0.494	0.370	X	X
	UL	0.150	X	0.245	0.291	X	X

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7.1. Results – ASE and 5% USE (9/13)

Candidate: 3GPP							
eMBB – Rural Urban (FDD)		**Configuration A (700 MHz)**					
Metric	**Link**	**M.2410**	**3GPP Min/Max**	**INRS**	**UofT**	**MEDIATEK**	**TPCEG**
ASE [bps/Hz/TRxP]	DL	3.300	5.040/17.370	11.600	6.152	5.640	5.774
	UL	1.600	3.750/15.550	4.349	6.951	4.637	6.243
5% USE [bps/Hz]	DL	0.120	0.130/0.570	0.174	0.162	0.128	0.155
	UL	0.045	0.090/0.630	0.617	0.248	0.231	0.113

7.1. Results – ASE and 5% USE (10/13)

Candidate: 3GPP						
eMBB – Rural Urban (TDD)		**Configuration A (700 MHz)**					
Metric	**Link**	**M.2410**	**3GPP** Min/Max	**INRS**	**UofT**	**MEDIATEK**	**TPCEG**
ASE [bps/Hz/TRxP]	DL	3.300	5.040/17.370	9.609	7.490	X	X
	UL	1.600	3.750/15.550	3.626	5.872	X	X
5% USE [bps/Hz]	DL	0.120	0.130/0.570	0.171	0.159	X	X
	UL	0.045	0.090/0.630	0.334	0.193	X	X

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7.1. Results – ASE and 5% USE (11/13)

Candidate: 3GPP						
eMBB – Rural Urban (FDD)		**Configuration B (4 GHz)**				
Metric	**Link**	**M.2410**	**3GPP Min/Max**	**INRS**	**UofT**	**MEDIATEK**	**TPCEG**
ASE [bps/Hz/TRxP]	DL	3.300	5.960/21.110	13.892	6.480	11.640	11.063
	UL	1.600	2.700/21.300	4.102	7.125	3.988	6.231
5% USE [bps/Hz]	DL	0.120	0.120/2.110	0.278	0.187	0.452	0.321
	UL	0.045	0.020/0.340	0.145	0.189	0.190	0.126

7.1. Results – ASE and 5% USE (12/13)

Candidate: 3GPP						
eMBB – Rural Urban (TDD)		**Configuration B (4 GHz)**					
Metric	**Link**	**M.2410**	**3GPP Min/Max**	**INRS**	**UofT**	**MEDIATEK**	**TPCEG**
ASE [bps/Hz/TRxP]	DL	3.300	5.960/21.110	10.384	13.144	X	X
	UL	1.600	2.700/21.300	2.907	3.361	X	X
5% USE [bps/Hz]	DL	0.120	0.120/2.110	0.349	0.370	X	X
	UL	0.045	0.020/0.340	0.195	0.132	X	X

7.1. Results – ASE (13/13)

Candidate: 3GPP						
eMBB – Rural Urban (FDD)	**Configuration C – LMLC (700 MHz)**					
Metric	**Link**	**M.2410**	**3GPP** Min/Max	**INRS**	**UofT**	**Huawei**	**Ericsson**
ASE [bps/Hz/TRxP]	DL	3.300	3.900/19.290	10.521	…	8.137	5.563
	UL	1.600	2.700/10.590	3.500	…	4.104	4.754

⚠ As stated in **ITU-R M.2410**, the performance requirement in terms of 5th percentile user spectral efficiency for Rural-eMBB is not applicable to Rural-eMBB LMLC (low mobility large cell).

7.2. Results - Mobility (1/12)

Candidate: 3GPP						
eMBB – Indoor Hotspot (FDD/UL)	**Configuration A (4 GHz, 10 km/h)**					
Metric	**Link**	**M.2410**	**3GPP Min/Max**	**INRS**	**UofT**	**Huawei**	**CATT**
Mobility [bps/Hz]	**LOS**	1.500	1.590/3.850	…	…	2.050	1.840
	NLOS	1.500	1.590/3.850	…	…	1.750	2.130

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7.2. Results - Mobility (2/12)

Candidate: 3GPP						
eMBB – Indoor Hotspot (TDD/UL)	**Configuration A (4 GHz, 10 km/h)**					
Metric	**Link**	**M.2410**	**3GPP Min/Max**	**INRS**	**UofT**	**Huawei**	**CATT**
Mobility [bps/Hz]	**LOS**	1.500	1.590/3.850	…	…	1.940	2.070
	NLOS	1.500	1.590/3.850	…	…	1.590	1.780

7.2. Results - Mobility (3/12)

Candidate: 3GPP						
eMBB – Indoor Hotspot (FDD/UL)		**Configuration B (30 GHz, 10 km/h)**				
Metric	**Link**	**M.2410**	**3GPP Min/Max**	**INRS**	**UofT**	**SAMSUNG**	**CATT**
Mobility [bps/Hz]	**LOS**	1.500	2.140/4.760	…	…	3.010	X
	NLOS	1.500	2.140/4.760	…	…	4.760	X

7.2. Results - Mobility (4/12)

Candidate: 3GPP						
eMBB – Indoor Hotspot (TDD/UL)		**Configuration B (30 GHz, 10 km/h)**				
Metric	**Link**	**M.2410**	**3GPP Min/Max**	**INRS**	**UofT**	**Sharp**	**CATT**
Mobility [bps/Hz]	**LOS**	1.5	2.140/4.760	…	…	2.150	X
	NLOS	1.5	2.140/4.760	…	…	2.140	X

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7.2. Results - Mobility (5/12)

Candidate: 3GPP						
eMBB – Dense Urban (FDD/UL)	**Configuration A (4 GHz, 30 km/h)**					
Metric	**Link**	**M.2410**	**3GPP Min/Max**	**INRS**	**UofT**	**Huawei**	**CATT**
Mobility [bps/Hz]	**LOS**	1.120	1.280/4.580	2.260	2.210	2.190	2.350
	NLOS	1.120	1.280/4.580	1.907	1.950	1.890	2.060

7.2. Results - Mobility (6/12)

Candidate: 3GPP						
eMBB – Dense Urban (TDD/UL)		**Configuration A (4 GHz, 30 km/h)**				
Metric	**Link**	**M.2410**	**3GPP Min/Max**	**INRS**	**UofT**	**Huawei**	**CATT**
Mobility [bps/Hz]	**LOS**	1.120	1.280/4.580	2.2104	2.060	1.620	X
	NLOS	1.120	1.280/4.580	2.1461	1.790	1.830	X

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7.2. Results - Mobility (7/12)

Candidate: 3GPP						
eMBB – Dense Urban (FDD/UL)		**Configuration B (30 GHz, 30 km/h)**				
Metric	**Link**	**M.2410**	**3GPP Min/Max**	**INRS**	**UofT**	**Huawei**	**CATT**
Mobility [bps/Hz]	**LOS**	1.120	1.230/3.220	2.242	...	X	X
	NLOS	1.120	1.230/3.220	1.890	1.180	X	1.240

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7.2. Results - Mobility (8/12)

Candidate: 3GPP						
eMBB – Dense Urban (TDD/UL)		**Configuration B (30 GHz, 30 km/h)**				
Metric	**Link**	**M.2410**	**3GPP Min/Max**	**INRS**	**UofT**	**Huawei**	**CATT**
Mobility [bps/Hz]	**LOS**	1.120	1.230/3.220	1.751	…	X	X
	NLOS	1.120	1.230/3.220	1.662	…	X	X

7.2. Results - Mobility (9/12)

Candidate: 3GPP						
eMBB – Rural Urban (FDD/UL)		**Configuration A (700 MHz, 120 km/h)**				
Metric	**Link**	**M.2410**	**3GPP Min/Max**	**INRS**	**UofT**	**Huawei**	**CATT**
Mobility [bps/Hz]	**LOS**	0.800	0.850/2.910	2.660	2.570	2.900	X
	NLOS	0.800	0.850/2.910	2.545	2.130	2.320	X

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7.2. Results - Mobility (10/12)

Candidate: 3GPP						
eMBB – Rural Urban (TDD/UL)		**Configuration A (700 MHz, 120 km/h)**				
Metric	**Link**	**M.2410**	**3GPP Min/Max**	**INRS**	**UofT**	**Huawei**	**CATT**
Mobility [bps/Hz]	**LOS**	0.800	0.850/2.910	2.308	2.180	2.630	X
	NLOS	0.800	0.850/2.910	2.191	1.920	2.100	X

7.2. Results - Mobility (11/12)

Candidate: 3GPP						
eMBB – Rural Urban (FDD/UL)		**Configuration B (4 GHz, 120 km/h)**				
Metric	**Link**	**M.2410**	**3GPP Min/Max**	**INRS**	**UofT**	**Huawei**	**CATT**
Mobility [bps/Hz]	**LOS**	0.800	1.020/2.750	2,537	2.620	2.900	X
	NLOS	0.800	1.020/2.750	2,376	2.150	2.310	X

7.2. Results - Mobility (12/12)

Candidate: 3GPP						
eMBB – Rural Urban (TDD/UL)		**Configuration B (4 GHz, 120 km/h)**					
Metric	**Link**	**M.2410**	**3GPP Min/Max**	**INRS**	**UofT**	**Huawei**	**CATT**
Mobility [bps/Hz]	**LOS**	0.800	1.020/2.750	2.451	2.140	2.630	X
	NLOS	0.800	1.020/2.750	1.935	1.940	2.090	X

7.3. Results – Connection Density (1/2)

Candidate: 3GPP						
Urban Macro – mMTC (FDD/UL)	**Configuration A (700 MHz, ISD = 1732 m)**					
Metric	**M.2410**	**3GPP Min/Max**	**INRS**	**UofT**	**Huawei**	**Ericsson**
Connection density [devices/km^2]	**1,000,000**	**1,267,000/ 1,503,000**	**1,458,509**	**1,518,832**	**1,465,000**	**1,575,368**

7.3. Results – Connection Density (2/2)

Candidate: 3GPP						
Urban Macro – mMTC (FDD/UL)	**Configuration B (700 MHz, ISD = 500 m)**					
Metric	**M.2410**	**3GPP Min/Max**	**INRS**	**UofT**	**Huawei**	**Ericsson**
Connection density [devices/km²]	1,000,000	36,008,000/ 36,324,000	…	...	35,021,000	29,844,621

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8. Conclusions

o   Work is still in progress to finish adjustments of the simulator to account for different features specific to 3GPP SRITs and ETSI candidates.

o   New mobility along with new spectral efficiency results have been added here since the last meeting.

o   Simulations at system then link levels already done to assess the reliability metric. Last calculations step is in progress.

Questions?

Thank you!