TTA SPG33

IMT-2020 EVALUATION REPORT
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Chair of TTA SPG33

Introduction to TTA SPG33

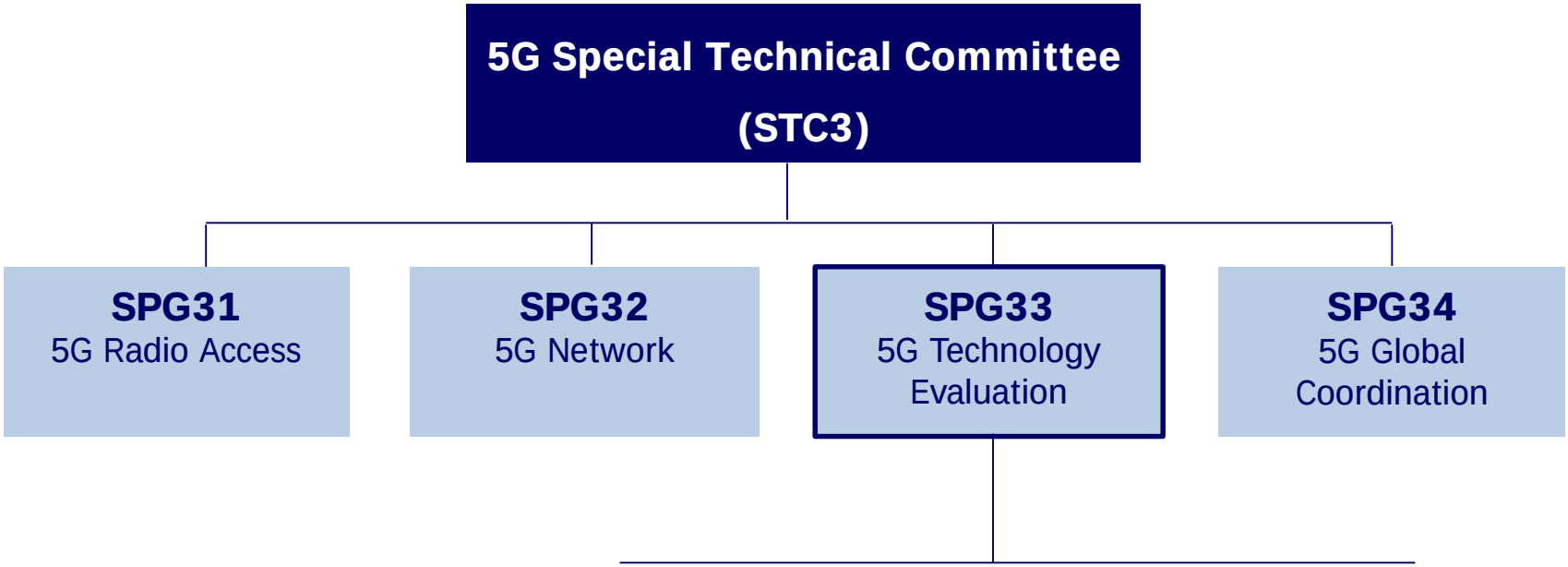
TTA SPG33's Evaluation of 3GPP 5G NR

-. Service and Spectrum

-. 15 Technical Performances

Conclusion and Final Remarks

TTA Special Project Group 33



ToR (Terms of Reference)

- IEG activities for IMT-2020
- Develop/Submit evaluation report of IMT-2020 candidate technology(ies)

About TTA SPG33

- Established July 6, 2017
  - Registered as an IEG at the same month
- Members
  - About 30 members from Industry/Research Institutes/Academia
- Chairman
  - Prof. OH, Seong-Jun, Korea University
  - (email) seongjun@korea.ac.kr

TTA SPG33 Work Scope

- Independent Evaluation Group registered in ITU-R
  - Terms of Reference includes
    - Evaluate proposals of IMT-2020 RIT/SRIT
    - Develop / Submit the report(s) to ITU-R
    - Cooperate and coordinate with other evaluation groups

- Complementary Works
  - Check if the proposal(s) satisfies the requirements according to the guidelines of ITU-R M.2412
  - May provide complementary evaluation works in order to make sure of evaluation results against possible unclear issue, if any

- Views on the other group's Evaluation Works
  - May provide SPG33 views on the evaluation works from other registered evaluation groups based on the consensus among TTA SPG33 members, if necessary.

TTA SPG33 Working Methods

- Meeting
  - Regularly, 3-4 times per year
  - Information sharing regarding IMT-2020
- Seminar/Workshop
  - Yearly, open to public
  - Evaluation progress report
- Evaluation Report based on Members' contributions
  - Candidate technology(ies) to evaluate : **3GPP 5G NR**
  - **Ericsson/Intel/LGE/Nokia/Qualcomm/Samsung/Korea Univ.**

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From Compliance template for service & spectrum

- Is the proposal able to support a range of services across different usage scenarios (eMBB, URLLC, and mMTC)?
  - TTA SPG33 confirms that 3GPP 5G NR supports all three usage scenarios
- Is the proposal able to utilize at least one frequency band identified for IMT in the ITU Radio Regulations?
  - TTA SPG33 confirms that 3GPP 5G NR utilizes frequency band identified for IMT in the ITU Radio Regulations from TS38.101-1/2 and TS38.104.
- Is the proposal able to utilize the higher frequency range/band(s) above 24.25 GHz?
  - TTA SPG33 confirms that 3GPP 5G NR utilizes frequency band above 24.25 GHz from TS38.101-2 and 38.104.

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Three Usage Scenarios and 15 Requirements

Technical requirements 5.2.4.3.1 – 5.2.4.3.15	Usage scenarios applicability		
	eMBB	mMTC	URLLC
1. Peak date rate	√		
2. Peak spectral efficiency	√		
3. User experience data rate	√		
4. 5th percentile user spectral efficiency	√		
5. Average spectral efficiency	√		
6. Area traffic capacity	√		
7. User plane latency	√		√
8. Control plane latency	√		√
9. Connection density		√	
10. Energy efficiency	√		
11. Reliability			√
12. Mobility classes	√		
13. Mobility traffic channel link data rate	√		
14. Mobility interruption time	√		√
15. Bandwidth	N/A		

Peak Data Rate (1/15)

- Requirements
  - **DL 20 Gbit/s**
  - **UL 10 Gbit/s**
- Contributions – Ericsson/Intel/Samsung
- Summary of Evaluation Results
  - FDD/TDD and FR1/FR2 are all jointly considered
  - Overheads considered : SSB, TRS, PDCCH, DM-RS, PT-RS, CSI-RS, PUCCH and SRS
  - Overhead percentages range from 8 – 18 %
  - After appropriate number of component carriers, peak data rate can be achieved
  - Table below is an example Gbit/s of TDD FR2 from Intel

SCS (kHz)		50 MHz	100 MHz	200 MHz	400 MHz
60	DL	34.48	68.95	137.91	-
	UL	18.92	37.84	75.68	-
120	DL	33.43	68.95	137.91	275.82
	UL	18.35	37.84	75.68	151.36

Peak Spectral Efficiency (2/15)

- Requirements
  - **DL 30 bit/s/Hz**
  - **UL 15 bit/s/Hz**
- Contributions – Ericsson/Intel/Samsung
- Evaluation Results
  - Same analysis method as peak data rate
  - Both FR1 and FR2 meet the requirements
  - Results for FR2 are shown below

SCS (kHz)		50 MHz	10 0MHz	200 MHz	400 MHz
60	DL	42.67	43.13	43.37	48.50
	UL	23.39	25.59	23.69	
120	DL	40.68	42.80	43.21	45.11
	UL	22.27	23.53	23.60	23.70

User Experienced Data Rate (3/15)

- Requirements (in Dense Urban eMBB)
  - **DL 100 Mbit/s**
  - **UL 50 Mbit/s**
- Contributions – Ericsson/Intel/LGE/Nokia/Samsung
- Evaluation Results
  - All the contributions calculate the required bandwidths (in MHz) in FR1, shown below
  - Under support bandwidth configurations of 3GPP 5G NR, it can meet the user experienced data rate targets for both downlink and uplink in FR1

	Ericsson	Intel	LGE	Nokia	Samsung
DL	317	366	350	302	350
UL	296	206	160	304	

Spectral Efficiencies (4-5/15) – Indoor Hotspot (1/2)

- Requirements
  - **5th percentile DL/UL – 0.3/0.21 (bit/s/Hz)**
  - **Average DL/UL – 9/6.75 (bit/s/Hz/TRxP)**
- Contributions
  - Ericsson/Intel/LGE/Nokia/Qualcomm/Samsung/Korea Univ.
- Evaluation Results from 8 configurations
  - 4GHz 12TRxP
  - 4GHz 32TRxP
  - 30GHz 12TRxP
  - 30GHz 36TRxP
  - 4GHz with Larger BW 12 TRxP
  - 4GHz with Larger BW 36 TRxP
  - 30GHz with Larger BW 12 TRxP
  - 30GHz with Larger BW 36 TRxP

Spectral Efficiencies (4-5/15) – Indoor Hotspot (2/2)

- As an example, 12 TRxP with 4GHz and 30 GHz
  - Intel/LGE/Nokia/Samsung/Korea Univ. – 4GHz
  - Ericsson/Qualcomm – 30 GHz

	Category	Channel model	Req	Ericsson	Intel	LGE	Nokia	Qualcomm	Samsung	KU	Note
Average	DL	A	**9**	13.900 tdd	10.627 fdd 8.770 tdd	11.450	9.8 fdd 10.054 tdd	12.034 tdd	13.160	10.124	MU-MIMO
		B				11.470					
	UL	A	**6.75**			7.968		6.900 tdd		9.570	SU-MIMO
		B				6.927					
		A		10.190 tdd	13.949 fdd 12.913 tdd		7.329				MU-MIMO
		B									
5th percentile	DL	A	**0.3**	0.348 tdd	0.398 fdd 0.328 tdd	0.339	0.350 fdd 0.452tdd	0.486 tdd	0.330	0.719	MU-MIMO
		B				0.343					
	UL	A	**0.21**			0.434		0.300 tdd		0.493	SU-MIMO
		B				0.431					
		A		0.312 tdd	0.592 fdd 0.548 tdd		0.396				MU-MIMO
		B									

Spectral Efficiencies (4-5/15) – Dense Urban (1/2)

- Requirements
  - **5th percentile DL/UL – 0.225/0.15 (bit/s/Hz)**
  - **Average DL/UL – 7.8/5.4 (bit/s/Hz/TRxP)**
- Contributions
  - Ericsson/Intel/LGE/Nokia/Qualcomm/Samsung/Korea Univ.
- Evaluation Results from 2 configurations
  - 4GHz
  - 4GHz with Larger Bandwidth

Spectral Efficiencies (4-5/15) – Dense Urban (2/2)

- 4GHz Results (Larger BW is not shown below)

	Category	Channel model	Req	Ericsson	Intel	LGE	Nokia	Qualcomm	Samsung	KU	Note
Average	DL	A	**7.8**	12.200 tdd	14.814 fdd 12.245 tdd	9.710	9.200		10.650	8.966	MU-MIMO
		B				9.630		10.776 tdd			
	UL	A	**5.4**			6.502 fdd				6.720	SU-MIMO
		B				6.431 fdd					
		A		7.280 tdd	22.479 fdd 20.808 tdd		6.735 fdd				MU-MIMO
		B						5.513 tdd			
5th percentile	DL	A	**0.225**	0.296 tdd	0.537 fdd 0.443 fdd	0.289	0.330		0.308	0.443	MU-MIMO
		B				0.309		0.361 tdd			
	UL	A	**0.15**			0.343 fdd				0.201	SU-MIMO
		B				0.310 fdd					
		A		0.163 tdd	0.528fdd 0.488tdd		0.277 fdd				MU-MIMO
		B						0.174 tdd			

Spectral Efficiencies (4-5/15) – Rural (1/2)

- Requirements
  - **5th percentile DL/UL – 0.12/0.045 (bit/s/Hz)**
  - **Average DL/UL – 3.3/1.6 (bit/s/Hz/TRxP)**
- Contributions
  - Ericsson/Intel/LGE/Nokia/Qualcomm/Samsung/Korea Univ.
- Evaluation Results from 6 configurations
  - 700 MHz
  - 4 GHz
  - LMLC
  - 700 MHz with Larger Bandwidth
  - 4 GHz with Larger Bandwidth
  - LMLC with Larger Bandwidth

Spectral Efficiencies (4-5/15) – Rural (2/2)

- An example, 4GHz

eMBB – Rural			4GHz								
	Category	Channel model	Req.	Ericsson	Intel	LGE	Nokia	Qualcomm	Samsung	KU	Note
Average	DL	A	**3.3**	17.375 tdd	18.007	12.580	9.700 fdd 8.658 tdd			10.499	MU-MIMO
		B				11.960		10.361 tdd	12.290		
	UL	A	**1.6**			3.525 fdd (1x32) 6.267 fdd (2x32)				4.317	SU-MIMO
		B				6.160 fdd					
		A		10.731 tdd	23.009 fdd 21.301 tdd		8.913 fdd				MU-MIMO
		B						9.204 tdd			
5th percentile	DL	A	**0.12**	0.425 tdd	0.471	0.120	0.269 fdd 0.190 tdd			0.657	MU-MIMO
		B				0.126		0.129 tdd	0.290		
	UL	A	**0.045**			0.140 fdd (1x32) 0.234 fdd (2x32)	0.269			0.0549	SU-MIMO
		B				0.187 fdd					
		A		0.073 tdd	0.283 fdd 0.262 tdd		0.123 fdd				MU-MIMO
		B						0.110 tdd			

Area Traffic Capacity (6/15)

- Requirements (DL in Indoor Hotspot eMBB)
  - **10 Mbit/s/m²**
- Contributions – Ericsson/Intel/LGE/Nokia/Samsung
- Evaluation Results
  - All the contributions calculates the required bandwidths (in MHz)
  - 12 TRxP are assumed. For Intel and Samsung, both 12/36 TRxP results are shown.
  - Under support bandwidth configurations of 3GPP NR, it can meet the area traffic capacity target

	Ericsson	Intel	LGE	Nokia	Samsung
4GHz		529/167	450	510	400/130
30GHz	219	641/209			

User Plane Latency (7 / 15)

- Requirements
  - **4 ms for eMBB**
  - **1 ms for URLLC**

- Contributions – Ericsson/Nokia

- Evaluation Results
  - From Ericsson (there exists small number of retransmissions for HARQ)
    - FDD 4ms by 15 kHz SCS
    - FDD 1ms by 15 kHz SCS, mini-slots and configured UL grants
    - TDD 4ms by 15 kHz SCS, mini-slots and configured UL grants
    - TDD 1ms by 120 kHz SCS, mini-slots and configured UL grants.

  - From Nokia (10% retransmission assumption)
    - Regular UE (7-symbol scheduling allocation)
      - » 4ms : DL for all SCS and UL with 30 or higher kHz SCS
      - » 1ms : DL/UL SCS 120 or higher kHz SCS
    - Latency Optimized UE
      - » 4ms : DL/UL for all SCS
      - » 1ms : SCS 30 and 60 kHz using 2-symbol slot scheduling
    - For Static TDD of DDDXU
      - » Analysis above are for FDD or dynamic TDD
      - » Some limitations are applied

Control Plane Latency (8/15)

- Requirements
  - **20 ms for both eMBB and URLLC**
- Contributions – Ericsson/Nokia
- Evaluation Results
  - TDD results (in ms, and parenthesis in TTI) are shown, but FDD results are similar

SCS		Case 1 (DL-UL)			Case 2 (DL-DL-DL-DL-UL)		
		TTI = 4	TTI = 7	TTI = 14	TTI = 4	TTI = 7	TTI = 14
15 kHz	Ericsson	10	13	20	9.4	12	18
	Nokia		12 (24)	15 (15)		14.5 (29)	18 (18)
30 kHz	Ericsson	8	9.5	13	10.7	9	12
	Nokia		10.5 (42)	12 (24)		10.25 (41)	11.5 (23)
60 kHz	Nokia		9 (72)	9.5 (38)		9.5 (76)	10.25 (41)
120 kHz	Ericsson	6.7	7.3	8.5	6.9	7.6	9.3
	Nokia		8.125 (130)	8.5 (68)		8.3125 (133)	8.875 (71)

Connection Density (9/15)

- Requirements
  - **1,000,000 connections per km²**
- Contributions – Ericsson/Nokia
- Evaluation Results
  - Full Buffer NR simulation by Ericsson
    - Connection density is shown below under 180 kHz bandwidth

Conf A, UMA A	Conf A, UMA B	Conf B, UMA A	Conf B, UMA B
30,066,283	29,844,621	1,269,767	1,575,368

  - Non-Full Buffer NR simulation by Nokia
    - All packet transmissions were successful in fewer than 1000 HARQ attempts
    - The maximum delay time is less than 10 seconds and the packet outage rate at these loading levels is zero.

Energy Efficiency (10/15)

- Requirements
  - Shall have the capability to support **a high sleep ratio and long sleep duration**
- Contributions – Ericsson/Nokia
- Evaluation Results
  - 3GPP NR supports significantly longer network DTX durations and have a significantly larger DTX duration.

Reliability (11/15)

- Requirements
  - **1- 10^{-5} success probability of transmitting a layer 2 PDU of size 32 bytes within 1 ms in channel quality of coverage edge**
- Contributions – Ericsson/intel/Nokia
- Evaluation Results
  - After SLS to get the 5th percentile SINR,
  - Ericsson's observation
    - With 1 transmission using MCS1 the reliability target of 10-5 error can be met in DL and in UL with configured grant.
    - With MCS1 and a 7-os mini-slot, 46 PRBs are required for a 32B packet.
    - With 30kHz SCS and 7-os mini-slot 1 transmission can be made in FDD within 1ms.
  - Intel's observation
    - At least for Configuration A the requirements are fulfilled with single-shot transmission of PDCCH+PDSCH.
  - Nokia's observation
    - NR can meet the IMT-2020 reliability requirements for Configuration A (4 GHz) DL with a single transmission attempt with a NLoS channel.
    - NR can meet the IMT-2020 reliability requirements for Configuration A (4 GHz) UL with a single transmission attempt with a LoS channel.
    - NR can meet the IMT-2020 reliability requirements for Configuration B (700 MHz) DL and UL with a single transmission attempt with a NLoS channel.

Mobility Classes (12/15)

- Requirements
  - **Are the following mobility classes supported?**
    - **Indoor Hotspot eMBB – Stationary and Pedestrian**
    - **Dense Urban eMBB – Stationary, Pedestrian and Vehicular (up to 30 km/h)**
    - **Rural eMBB – Pedestrian, Vehicular, High speed vehicular**
- Contributions – Ericsson/Intel/Nokia/Samsung
- Evaluation Results
  - Based on the results of “Mobility Traffic Channel Link Data Rates”, shown in the next slides (13/15), mobility classes suggested for each test environment are supported.

Mobility for Traffic Channel Link Data (13/15) - 1/2

- Requirements
  - **Indoor Hotspot eMBB – 1.5 bit/s/Hz @ 10km/h**
  - **Dense Urban eMBB – 1.12 bit/s/Hz @ 30km/h**
  - **Rural eMBB – 0.8 bit/s/Hz @ 120km/h & 0.45 bit/s/Hz @ 500km/h**
- Contributions – Ericsson/Intel/Nokia/Samsung
- Evaluation Results
  - **Ericsson**'s contribution shows that the **required SINRs** for those traffic channel link data is **less than the median SINR**. For example, 7dB/3.5dB (NLOS/LOS) are required SNR to meet 1.12 bit/s/Hz @ 30 km/h Dense Urban eMBB test environments. Median SINR for DL and UL are at least 8.6 dB (minimum, UL model A).
  - For other contributions, the traffic channel link data rates are obtained and all of them exceed the requirements. Some of **those results are shown in the next slide.**

Mobility for Traffic Channel Link Data (13/15) - 2/2

	Speed (km/h)	Req.	Intel		Nokia		Samsung	
			SCS 15kHz	SCS 30kHz	FDD	TDD	LOS	NLOS
Indoor Hotspot	10	**1.5**	**3.207**	**2.991**	**1.84**	**1.50**	**4.85**	**2.98**
Dense Urban	30	**1.12**	**1.923**	**1.925**	**1.56**	**1.28**	**3.69**	**2.21**
Rural	120	**0.8**	**2.750**	**2.462**	**1.02**	**0.8**		
	500	**0.45**	**2.093**	**2.463**	**0.87**	**0.68**		

- Intel's results are from
  - 4GHz for all cases
  - Indoor Hotspot is from 12 TRxP
- Nokia's results for Dense Urban are from
  - (1,4,2) Rx Config
- Samsung's results are for DL

Mobility Interruption Time (14/15)

- Requirements
  - The shortest time duration supported by the system during which a user terminal cannot exchange user plane packets with any base station during transitions should be **0ms**
- Contributions – Ericsson
- Evaluation Results
  - 0ms mobility interruption time can be achieved in 3GPP NR Rel-15 due to
    - In intra-cell beam mobility
    - For CA operation, during addition and release of an SCell in response to mobility (no change to PCell).

Bandwidth (15/15)

- Requirements
  - At least **100 MHz**
  - Shall support bandwidths **up to 1 GHz** for operation in higher frequency bands (e.g. above 6 GHz)
  - Shall support **scalable** bandwidth
- Contributions – Ericsson
- Evaluation Results
  - Several 3GPP 5G NR configurations support bandwidths of 100 MHz and above
  - 3GPP 5G NR supports carrier aggregation of up to 16 component carriers in which case the supported NR carrier bandwidth exceeds 1 GHz
  - Bandwidth scalability is therefore, supported.

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Conclusion

3GPP 5G NR RIT meets the service, spectrum and technical requirements of IMT-2020

Future Plan

- Finalize the report in 34th ITU-R WP 5D meeting in Feb. 2020
- Cooperate with other IEG members and the proponents
- Discuss the IMT-2020 evaluation process