



Views on NOMA

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Summary NR NOMA studies

- NOMA was studied during Rel-14 NR SI
 - 14 NOMA schemes were evaluated
 - NOMA gains over OMA were demonstrated but with non-optimized OMA performance
 - No convergence on NOMA schemes
- NOMA is further studied in Rel-16
 - No convergence on NOMA schemes
 - 15 NOMA schemes were proposed, of which 13 schemes were evaluated in link level and 8 schemes were evaluated in system level
 - No realistic performance gain is demonstrated for NOMA schemes compared to Rel-15 PUSCH scheme based on current cases
 - In link-level, different NOMA schemes, with/without link/layer adaptation, perform similarly compared to Rel-15 PUSCH scheme (see slide 3)
 - In system-level, only if compared with non-optimized Rel-15 performance, NOMA demonstrated gain(see slides 4-5)
 - Complexity of several advanced receivers (e.g. EPA, MMSE hard IC, ESE) was analyzed
 - Several options listed for complexity analysis of the same receiver; no consensus on which option is more accurate
 - Tradeoff between performance and receiver complexity reduction is unclear, e.g. N_{RE}^{adj} for MMSE hard IC
 - No benefits justified from procedural change in support of NOMA
 - Observation concluded that random selection with DMRS/preamble selection leads to severely degraded performance
 - Benefits of asynchronous transmission have not been justified. No consensus to support asynchronous transmission
 - Various DMRS assumptions were used with different Tx/Rx changes in the evaluations. No evaluation performed aiming to justify DMRS extensions compared to Rel-15 NR DMRS

Key link level evaluation observations captured in TR38.812

- For LLS in mMTC/eMBB/URLLC scenarios with ideal channel estimation, equal SNR, zero TO/FO. and fixed MA signature allocation
 - For low TBS (per UE SE is less than 0.15 bps/Hz and total SE is less than 1.8 bps/Hz), as long as the simulation configuration, e.g., reasonable code rate, is appropriate, the performance difference between NOMA schemes/MA signatures is small, even when different receiver types are used.
- For LLS in some simulated cases (i.e., 15/17/19/20/26/27) with ideal channel estimation, equal SNR, zero TO/FO and fixed MA signature allocation
 - For medium to high TBS (per UE SE is within [0.3, 0.55] bps/Hz, and total SE is less than 3.6 bps/Hz), as long as the simulation configuration, e.g., reasonable code rate, is appropriate, the performance difference between NOMA schemes/MA signatures is small.
 - Results with lower code rate (e.g. LDPC coding rate < 0.5) show better performance than the results with higher code rate (e.g. LDPC coding rate > 0.5).
- Based on simulations of some cases (i.e., cases 1~5, cases 14~20), for LLS with realistic channel estimation, equal SNR distribution, zero TO/FO and fixed MA signature allocation, it is observed that
 - Up to 2~4 dB performance degradation is observed compared to ideal channel estimation for mMTC/eMBB scenario.
 - Up to 5 dB performance degradation is observed compared to ideal channel estimation for URLLC scenario.
 - Different performance degradation levels may be due to different channel estimation algorithm and DMRS extension methods.
 - The lower the SNR operation point is, the larger the performance degradation due to realistic CE can be observed
 - Higher number of UEs have larger performance degradation than lower number of UEs under the same channel condition and the same TBS for each individual case.
- Based on simulations of some cases (i.e., 32/33/34/35) with larger standard deviation of SNR difference, for LLS with ideal channel estimation, under unequal SNR, and fixed MA signature allocation, it is observed that as long as the simulation configuration is appropriate, the performance difference between NOMA schemes/MA signatures is small, even when different receiver types are used
 - Performance loss of 1.1-3.2 dB can be observed with real channel estimation in multipath, where the losses are greater for the larger number of UEs or with greater SNR variation with for link level simulations.

Key system level evaluation observations captured in TR38.812

- For mMTC, the observations were captured as below; similar observations concluded for URLLC and eMBB scenario

For mMTC scenario, under the system-level evaluation assumptions as detailed in Table 9.2-1, relative to the evaluated OFDM waveform (using configured grant with multiple users in the same time and frequency resources) with MMSE-IRC or advanced receiver, the evaluated NOMA schemes with configured grant (without DMRS collision) can provide the results in Table 9.2-1:

- → In some simulated cases,
 - → time and frequency resource configuration per UE for the baseline is different from that per UE for evaluated NOMA schemes;
 - → Receivers used for the baseline and for the evaluated NOMA schemes are in some cases different and in other cases the same.
 - → Resource utilization of simulated NOMA schemes is 3 to 5 times than baseline.
- → In some other simulated cases,
 - → the time and frequency resource configuration per UE for the baseline is the same as that per UE for the evaluated NOMA scheme
 - → the same type of receiver is assumed for the baseline and the evaluated NOMA schemes
 - → Resource utilization of simulated NOMA schemes is comparable to baseline.
- → Different L2S mappings are used.
- → Within source 1, the ideal assumptions of inter-cell interference covariance matrix (non-block diagonal and genie-known to the receiver) is assumed.
- → Different baselines, different amount of optimization, and different choice of receiver types are used within different sources

- Performance of Rel-15 baseline is not optimized in majority system level evaluations, e.g.
 - Time-frequency resource allocation for Rel-15 baseline is different from that for NOMA schemes
 - Receiver for Rel-15 baseline is different from that for NOMA schemes
- Impractical assumption was made in some evaluations for NOMA schemes
 - e.g. ideal (genie-aided) inter-cell interference covariance matrix comprising both spatial and spreading domain correlation information

- With aligned simulation assumptions and practical assumptions, there are results showing NOMA schemes with Tx change perform similarly to the Rel-15 scheme (see next slide)

Discussion on system level results

Aligned chip EPA receiver for all schemes

Chip MMSE for SCMA/LCRS, block MMSE for MUSA/RSMA

mMTC	TBS (bytes)	NOMA schemes	PAR @1%PDR	SCMA gain over others
R1-1813922	20	SCMA	590	-
		MUSA	580	1.7%
SL-RSMA		580	1.7%	
Rel-15 scheme		590	0	
R1-1813977		60	SCMA	740
	MUSA		620	19.4%
	SL-RSMA		620	19.4%
	ML-RSMA		720	2.8%
	Rel-15 scheme		740	0

TBS (bytes)	NOMA schemes	PAR @1%PDR	SCMA gain over others
20	SCMA	580	-
	MUSA	580	0
	SL-RSMA	580	0
	Rel-15 scheme	580	0
60	SCMA	700	0
	MUSA	610	14.8%
	SL-RSMA	610	14.8%
	ML-RSMA	700	0
	Rel-15 scheme	700	0

URLLC	Tx option	NOMA schemes	PAR @95% ratio	SCMA gain over others
R1-1813923	TBS 60byte 60kHz, 7OS, 1 repetition	SCMA	2350	-
		MUSA	1690	39%
		SL-RSMA	1690	39%
		ML-RSMA	2290	2.5%
		Rel-15 scheme	2320	1.3%
	TBS 60byte 60kHz, 7OS, 2 repetitions	SCMA	2930	-
		MUSA	2170	35.1%
		SL-RSMA	2170	35.1%
		ML-RSMA	2810	4.3%
		Rel-15 scheme	2810	4.3%

Tx option	NOMA schemes	PAR @95% ratio	SCMA gain over others
TBS 60byte 60kHz, 7OS, 1 repetition	SCMA	2290	-
	MUSA	1690	35%
	SL-RSMA	1690	35%
	ML-RSMA	2290	0
	Rel-15 scheme	2290	0
TBS 60byte 60kHz, 7OS, 2 repetitions	SCMA	2810	-
	MUSA	2150	30%
	SL-RSMA	2150	30%
	ML-RSMA	2810	0
	Rel-15 scheme	2810	0

eMBB	TBS (bytes)	MA schemes	PAR @1%PDR	SCMA gain over others
R1-1813924	60	SCMA	5100	-
		MUSA	4950	3.03%
		SL-RSMA	4900	4.08%
		ML-RSMA	5050	0.99%
		Rel-15 scheme	5050	0.99%

TBS (bytes)	MA schemes	PAR @1%PDR	SCMA gain over others
60	SCMA	4800	-
	MUSA	4800	0
	SL-RSMA	4800	0
	ML-RSMA	4800	0
	Rel-15 scheme	4800	0

Key observations on random selection captured in TR38.812

- For the case with realistic channel estimation and random selection with potential MA signature collision (timing offset is within $[0, 1.5 \cdot \text{NCP}]$, non-zero FO, and SNR offset is within $\pm 3\text{dB}$)
 - When the TBS is small (i.e. 20 bytes), with 6 simultaneous activated UEs, based on the realistic UE detection by using 2-slot transmission time (e.g., 50% overhead for legacy preamble as the RS, without DMRS, preamble and data have the same BW, without assuming guard-band, with the pool size of 48 and 64), there is around 3.5 dB performance loss at 10% BLER, compared to random activation with no DMRS/MA signature collision and timing offset is within $[0, 0.5 \cdot \text{NCP}]$ and 1-slot transmission.

Note: this observation is based on single company's results

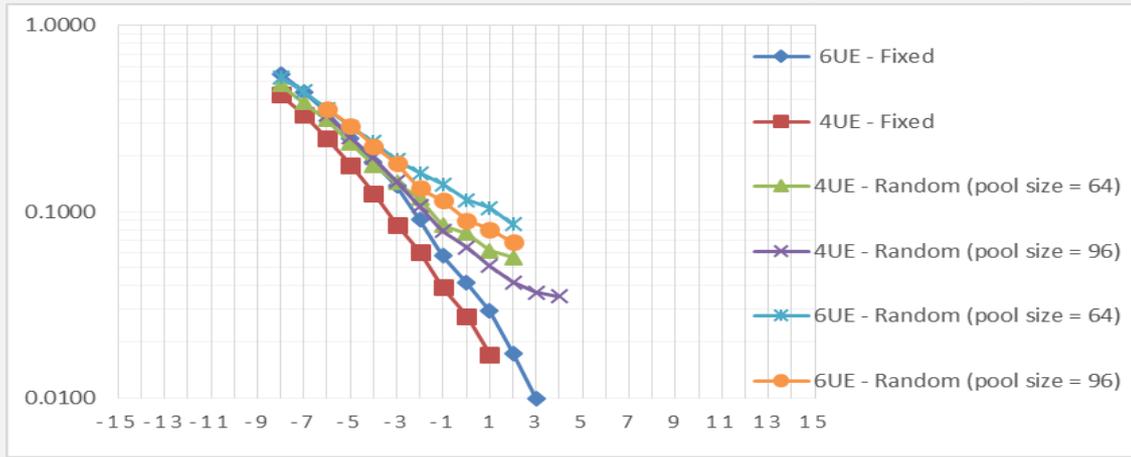
- When the TBS is small (i.e. 20 bytes), 10% BLER cannot be achieved for 4 and 6 UEs, with random selection (DMRS overhead of $2/7$ for pool size 24), for both realistic and ideal UE detection, with 1-slot transmission time.
- When the TBS is small (i.e. 20 bytes), with random activation (with realistic UE detection, DMRS overhead of $2/7$ for pool size 24, without DMRS/MA signature collision) of 1-slot transmission, the performance degradation at 10% BLER for 4, 6 and 8 UEs is about 1 dB compared to random activation without timing offset (with realistic UE detection, DMRS overhead of $1/7$ for pool size 24, without DMRS/MA signature collision)

Note: this observation is based on single company's results

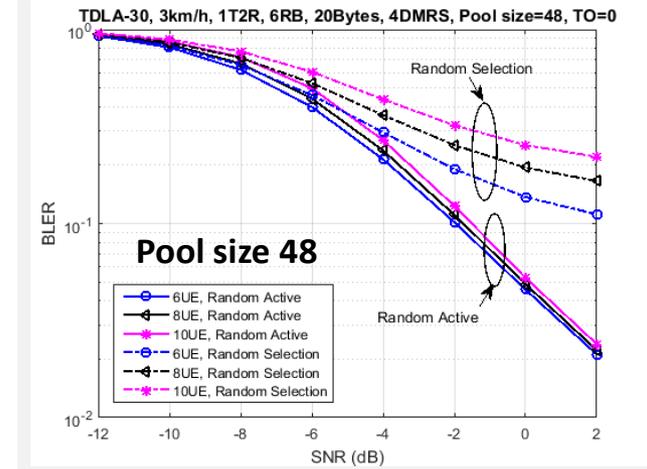
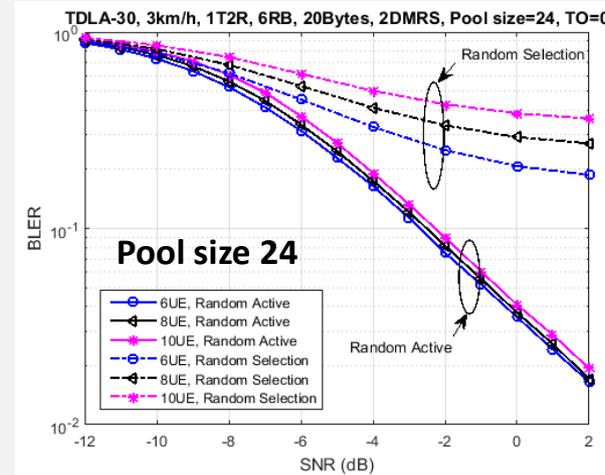
Evaluations on random selection with preamble/DMRS collision

- Multiple sources evaluated the performance of random selection with preamble/DMRS collision, and showed degraded performance

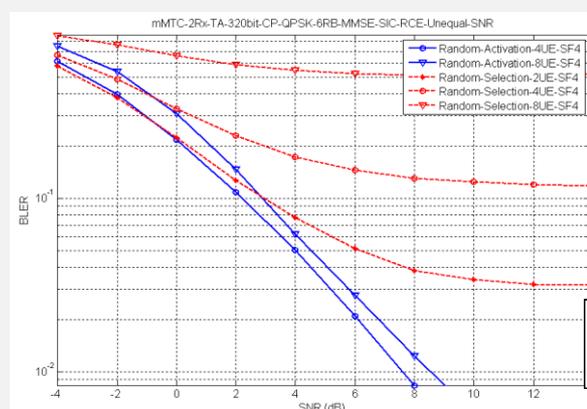
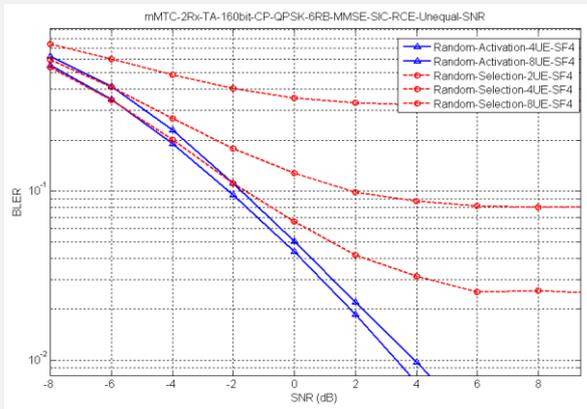
Performance of random selection (R1-1812174)



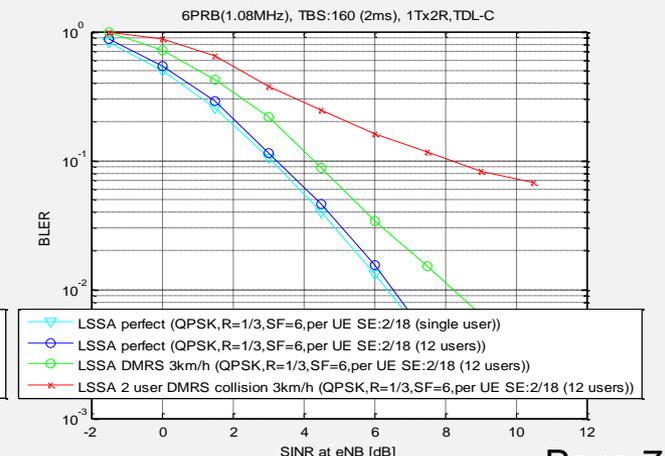
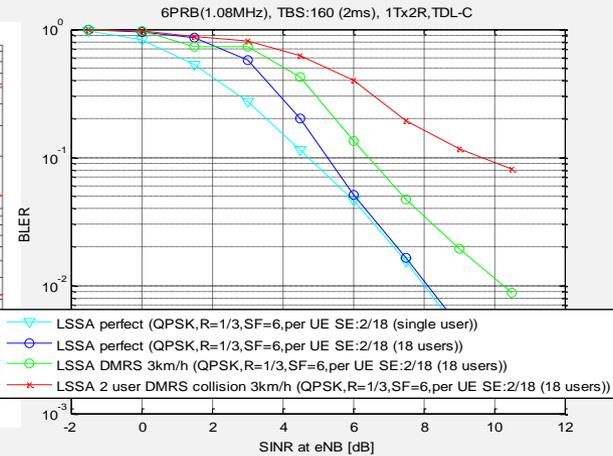
Performance of random selection (R1-1812189)



Performance of random selection (R1-1812611)



Performance of random selection (R1-1813482)



Recommendations

- Conclude the Rel-16 NOMA SI in RAN#82
- Consider NOMA in later release(s)

THANK YOU

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