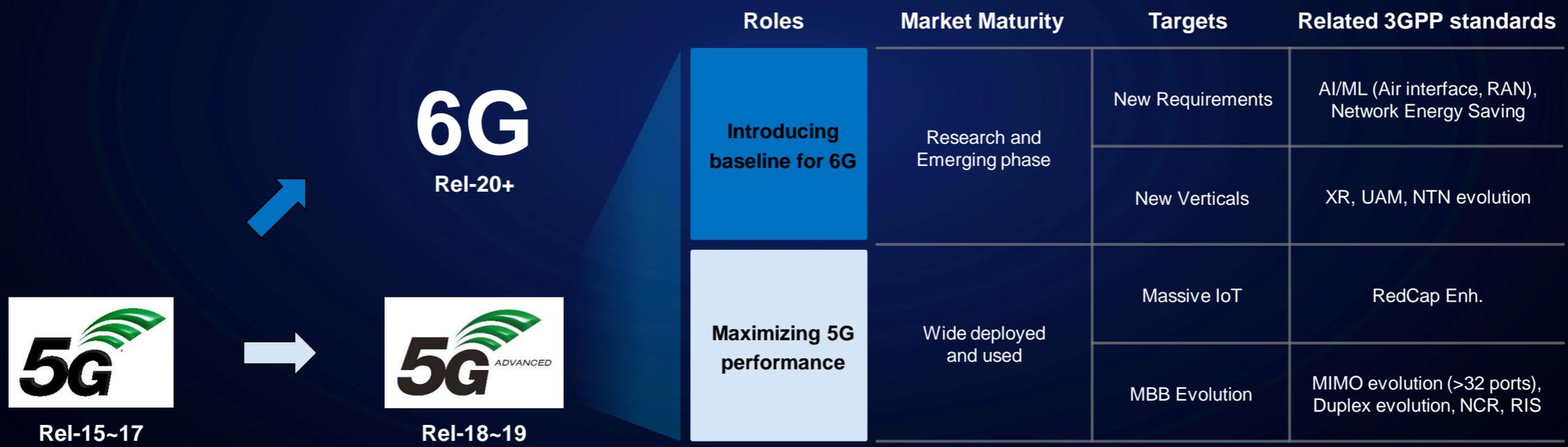


SK telecom's view on Rel-19



Introduction

- **‘5G-Advanced’ will serve as a bridge between 5G and 6G, and play the same role as LTE-Advanced Pro did in the past.**
 - ① **Maximizing 5G performance:** 5G will continue to be deployed and used for at least the next 5~10 years.
 - ② **Introducing baseline for 6G** (such as XR, UAM, NTN, AI/ML, NES): most of concepts and technologies will be adopted in 6G.



- **We believe ‘5G Lessons Learned’ should be considered when defining the 2nd release of 5G-Advanced (i.e., Rel-19), and it is critical to the success of 6G (SI expected in Rel-20).**

5G Lessons Learned

① **Massive MIMO is the most important technology that differentiates 5G from LTE in terms of spectral efficiency. It will be continued in 6G.**

- Without massive MIMO equipments, 5G has similar spectral efficiency with LTE.

Table 1. spectral efficiency comparison from measurement in the live network (30km/h)

RAT	Equipment	RSRP	DL MAC (Mbps)	RB (inc. 0)	RI	Spectral Efficiency (T-put / Layer / 15kHz)	Gain	MCS
NR (n78)	64TRx Radio	-64.95	1255.46	209.29	3.99	0.75	131%	24.84
	4TRx Radio	-64.73	1019.52	210.23	4.00	0.61	106%	21.17
LTE (5CC)	4/2TRx Radio	-71.02	482.61	348.79	2.41	0.57	Ref.	20.69

**64/96/128 Port
Massive MIMO, ...**

② **Cost-effective coverage extension technologies that can overcome the propagation attenuation of a given frequency band is required.**

- mmWave (FR2) is not successful in the market due to its coverage issues.
- candidate frequency band for each RAT continue to rise due to lack of spectrum and it is expected to be continue in 6G.

**Sub-band full duplex,
NCR, RIS, ...**

③ **There is still no 5G killer service that can feel the clear difference in service quality or cannot be supported unless it is 5G.**

- As cellular IoT was developed in LTE-A Pro, it is necessary to discover 5G killer service.

XR, NTN, UAM, ...

Prioritized Rel-19 items (SK telecom's view)

- **[MIMO] 64TRx MIMO and above in Rel-19 NR MIMO evolution (RAN1-led)** **RWS-230338**

 - Extending CSI-RS resource to 64/96/128 ports and defining related Type I codebook

- **[Duplex] SBFDD operation for random access in Rel-19 NR duplex evolution (RAN1-led)** **RWS-230339**

 - Random access coverage enhancement using SBFDD operation in RRC idle/inactive state

- **[NCR] Access/Backhaul link power control in Rel-19 NCR enhancement (RAN2-led)** **RWS-230340**

 - Access/backhaul link power control of NCR for interference mitigation and transmit power optimization

- **[NTN] Considerations on regenerative payload in Rel-19 NR NTN (RAN2-led)** **RWS-230341**

 - Support regenerative payload for non-terrestrial network in Rel-19 NR NTN

- **[NTN] High-Power UE for Rel-19 NR NTN (RAN4-led)** **RWS-230343**

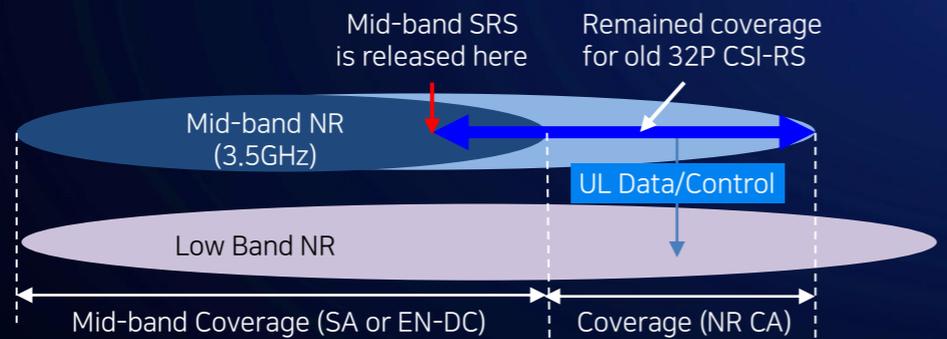
 - Support of higher power classes for NR NTN handheld UE.

64TRx MIMO and above (RAN1-led)

- **Motivation:** Many operators are deploying lots of 64TRx radio equipments now. However, beamforming flexibility of these new 64TRx radios cannot be fully utilized in below cases due to the current 32 ports CSI-RS limitation.

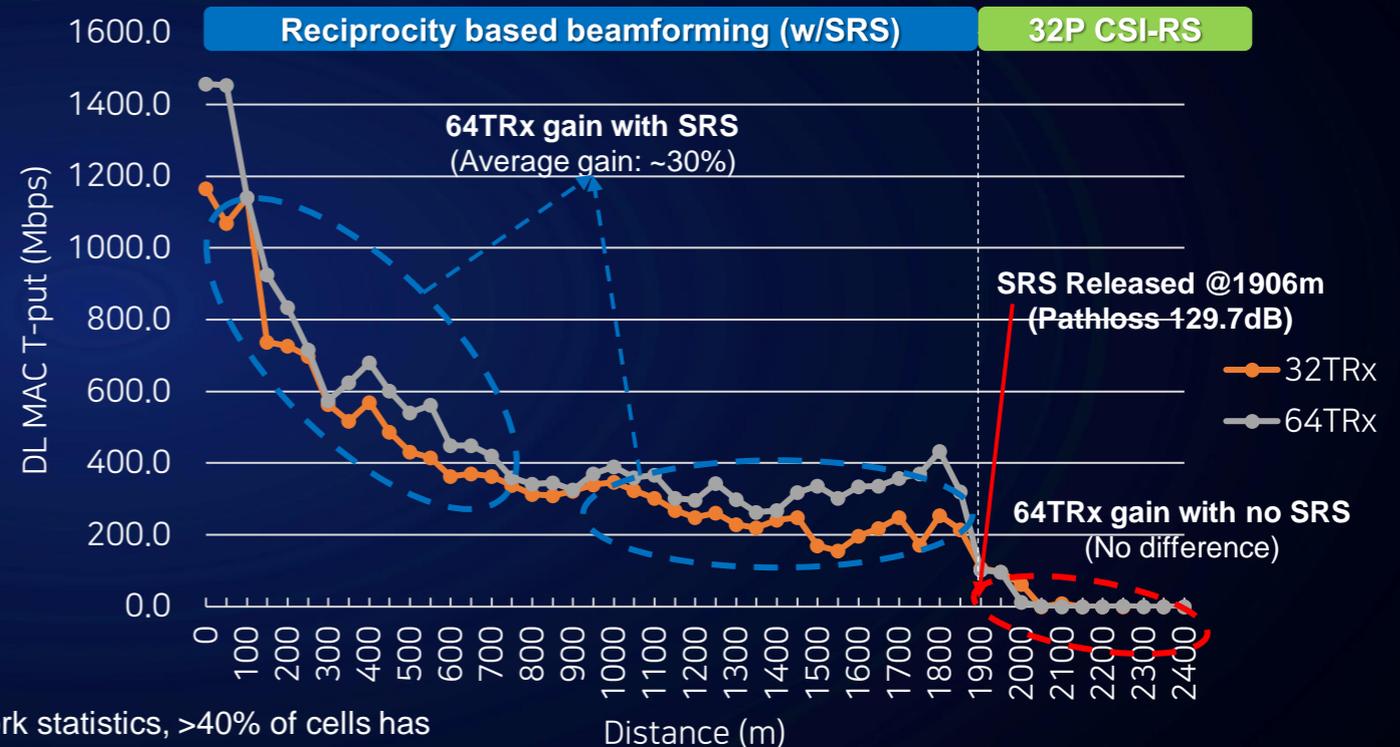
① **Cell Edge:** if SRS is released (due to its inherit UL power limitation), there is no performance difference between 32/64TRx radio in our field driving test as shown in figure 1.

② **Low/Mid-Band NR CA:** there is quite large mid-band 5G DL coverage for old 32P CSI-RS based operation even if new 64TRx equipments are installed for mid-band.



③ **Large number of UEs a Cell:** From SK telecom's commercial network statistics, >40% of cells has more than 16 active users during normal daytime already (=the maximum number of 10ms SRS antenna switching UEs in 'DDDSU' TDD Pattern with 10:2:2 special slot format).

Figure 1. DL performance comparison of 32/64 TRx radio in live network (Tx Power: 50.2/52dBm)



- **Objective:** Extending CSI-RS resource to 64/96/128 ports and defining related Type I codebook (e.g., $N_2 > 2$ when $N_1 = 8$)

SBFD operation for random access (RAN1-led)

- **Motivation:** Mid-band TDD (e.g., 3.5GHz) is main frequency range of NR in terms of global usage. In LOS environment, mid-band NR TDD coverage is limited by possible PRACH detection distance (not UL data channel)

① **UL QoS Coverage:** SBFD (sub-band full duplex) operation can enhance the NR data channel QoS coverage by utilizing increasing UL scheduling chance to reduce UL RB & MCS per each transmission.

② **PRACH Coverage:** Even if there are sufficient PRACH preamble formats in specification, limited continuous time duration for the uplink in TDD limits its allocation flexibility in real network.

only short preamble sequence can be used for DDDSU pattern with 30kHz SCS (=0.5ms UL slot duration) → Max. PRACH detection distance = 4.6km

Table 2. Mid-Band NR QoS coverage (UL 1Mbps, @3.65GHz)

Direction	QoS	UL 1Mbps	
		DDDSU	FDD (or XXXXU)
Tx	UE Tx Power (dBm)	23	23
	Duplex (DL/UL)	DDDSU	FDD (or XXXXU)
	UL RB	75	28
	MCS	0	0
	UE EIRP (dBm/RB)	4.2	8.5
Rx	BS Antenna Gain (dBi)	24.9	24.9
	Thermal Noise (dBm/RB)	-118.2	-118.2
	BS Noise Figure (dB)	4.0	4.0
	Thermal Noise at BS Rx (dBm/RB)	-114.2	-114.2
	Required SNR (dB)	-3.0	-3.0
	Received Signal Strength (dBm/RB)	-117.2	-117.2
	Max Allowable Pathloss (dB)	146.4	150.7
Max 2D Distance (UMa LOS, @3.65GHz, km)	9.15km	12.4km	

Table 3. NR PRACH cell dimensioning

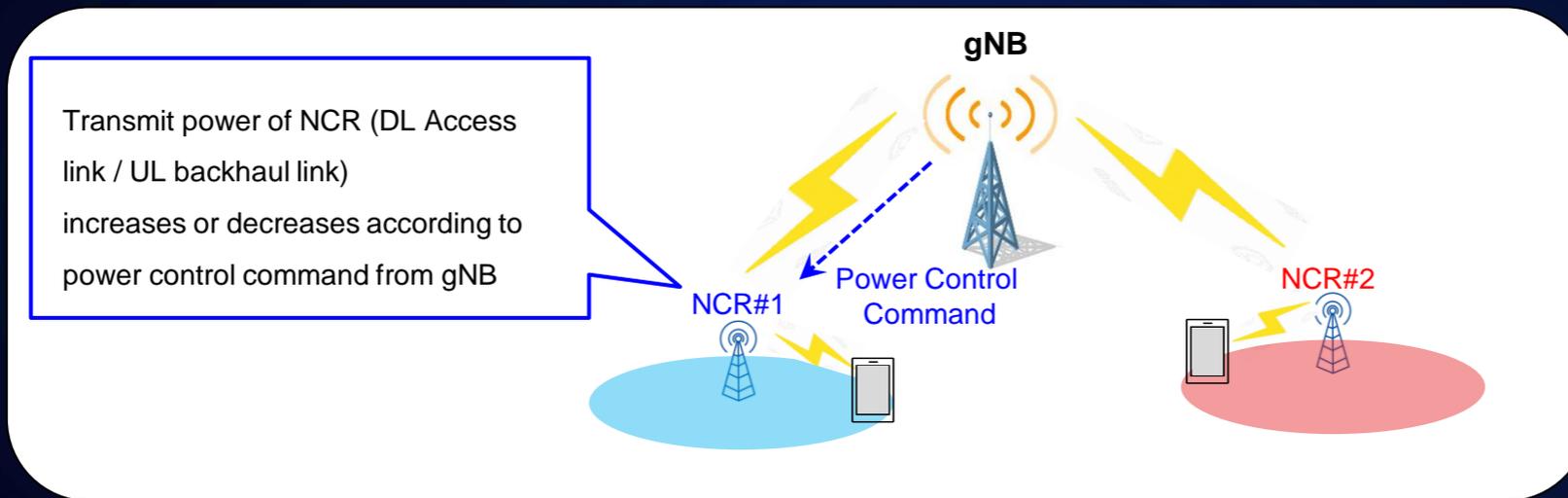
Category	Format	Maximum Cell Radius (m)			
		15kHz SCS	30kHz SCS	60kHz SCS	120kHz SCS
Short	A1	939	448	224	112
	A2	2110	871	435	217
	A3	3517	1302	651	325
	B1	586	232	116	58
	B2	1055	475	237	118
	B3	1758	871	435	217
	B4	3869	1302	651	325
	C0	5354	2130	1065	532
	C2	9301	4648	2324	1162
Long	0	12364 (SCS 1.25kHz)			
	1	57427 (SCS 1.25kHz)			
	2	22910 (SCS 5kHz)			
	3	14759 (SCS 5kHz)			

- **Objective:** Random access coverage enhancement using SBFD operation in RRC idle/inactive state

Access/Backhaul link Power control of NCR

- **Motivation:** Many NCR devices will be installed and operated for coverage extension. The performance of NCR devices is affected by interference among NCR devices.

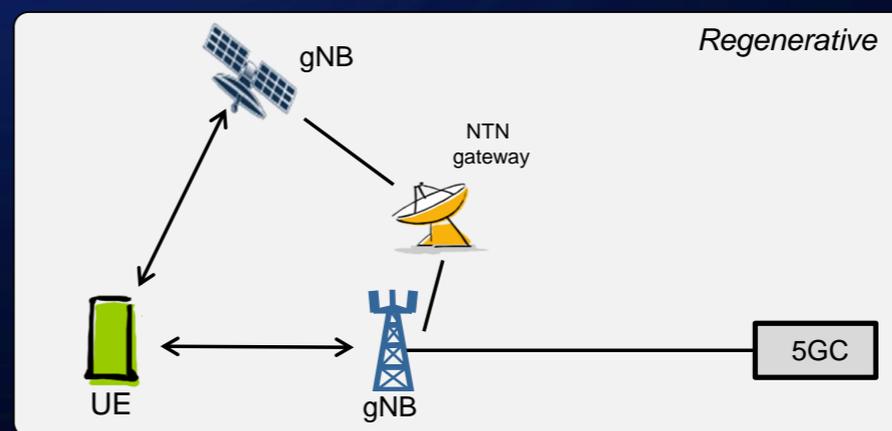
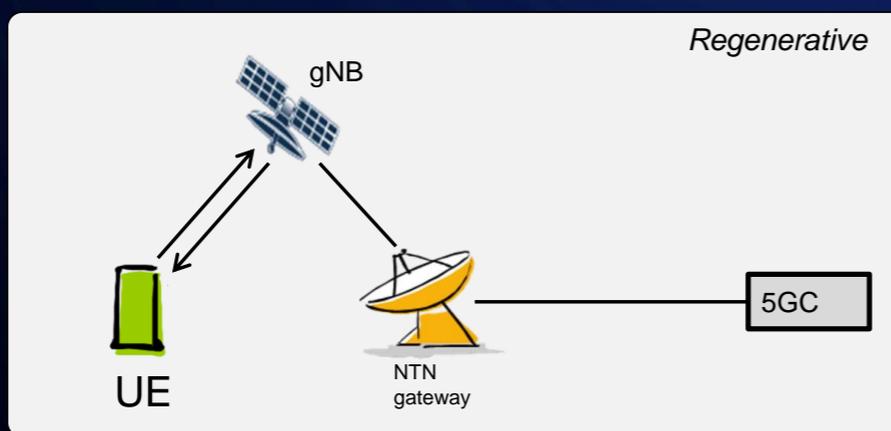
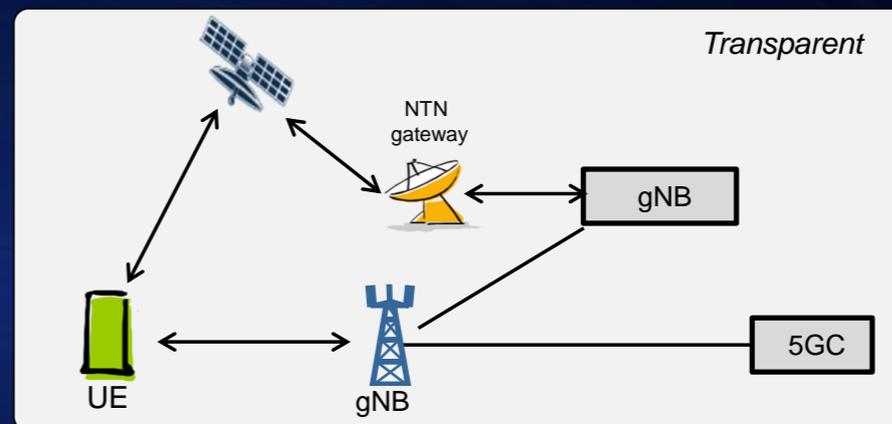
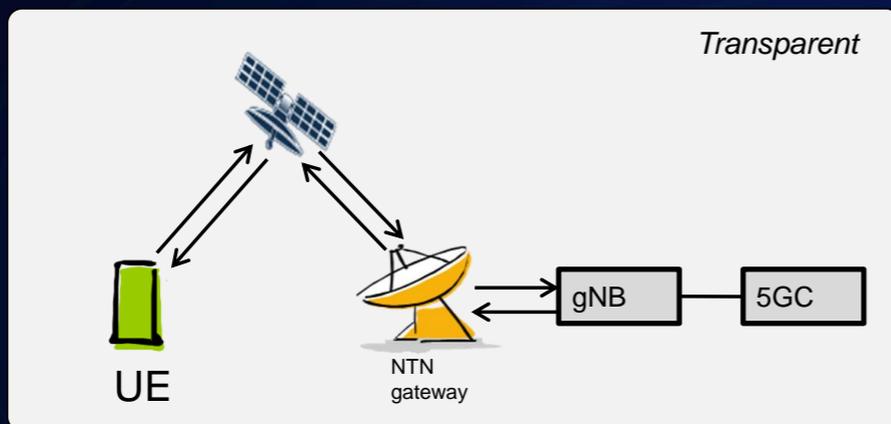
① Power control of NCR



- When NCR transmits DL access link and UL backhaul link, it causes interference to neighboring NCRs or UEs
 - Interference can be optimized by power control of each NCR
 - Power consumption can be reduced by optimizing signal amplification through power control
 - Power control command that can separately adjust the power of DL access link and UL backhaul link is required.
- **Objectives:** Interference mitigation among NCRs and transmission power optimization using power control. In addition, power control command can separately adjust the power of DL access link and UL backhaul link.

Regenerative payload for NR NTN (RAN2-led)

- **Motivation:** To enhance the user experience of mobile users, it's beneficial to support regenerative payload.
 - ① Thanks to the shorter UE-gNB distance, the delay between UE and gNB (i.e., NR Uu) is reduced compared with that using transparent payload.
 - ② In dual connectivity scenario, the PDCP latency would be reduced considering the retransmission (e.g., HARQ, RLC AM) at satellite.



[Delay between UE and gNB]

[Dual connectivity]

- **Objective:** Support regenerative payload for non-terrestrial network in Rel-19 NR NTN

High-Power UE for NR NTN (RAN4-led)

- **Motivation:** With antenna gain of -5.5 dBi, handheld UE with power class 3 may suffer from link budget deficiency.

① **NR NTN coverage bottleneck:** Considering link budget deficiency in NR NTN, it is needed to enhance the coverage of PUSCH and PRACH. Increasing the repetition level may be a solution, but it comes with the disadvantage of increased latency.

Table 1: Link budget calculation with -5.5 dBi antenna gain based on [R1-2205826]

Satellite parameters	LEO 1200 with Set 2 parameters (TR 38.811)					
UE transmit power [dBm]	23					
UE antenna gain [dBi]	-5.5					
Frequency [GHz]	2.00					
TX: EIRP [dBm]	17.5					
RX: G/T [dB/T]	-4.90					
Free space path loss [dB]	164.48					
Atmospheric loss [dB]	0.07					
Shadow fading margin [dB]	3					
Scintillation Loss [dB]	2.2					
Polarization loss [dB]	3					
Additional losses [dB]	0					
Type	PUSCH Msg3	PUSCH VoNR	PUCCH	PRACH format 2	PRACH format B4	PRACH format 0
Bandwidth [MHz]	0.36	0.72	0.18	1.048	2.16	1.048
Achievable CNR [dB]	-17.11	-20.12	-14.1	-21.75	-24.89	-21.75
Minimum required SNR [dB]	-14.6	-14.2		-18.5	-14.2	-13.3
SNR Gap [dB]	-2.51	-5.92		-3.25	-10.69	-8.45

Table 2: UE Power Class for NR NTN [TR38.101-5]

NR satellite band	Class 3 (dBm)	Tolerance (dB)
n256	23	±2
n255	23	±2

② **High data rate service:** As satellite hardware evolves, it is expected that satellites are becoming capable of providing high data rate services. To fully utilize this capability, High-power UE is necessary.

- **Objective:** Support of higher power classes for NR NTN handheld UE.

Thank You.

