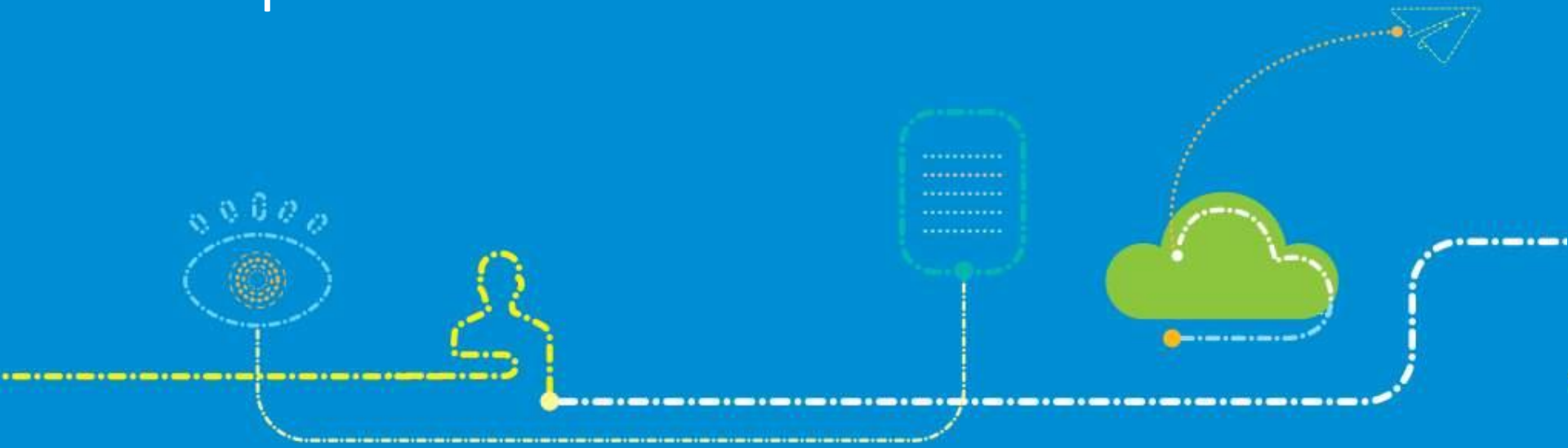
3GPP TSG RAN #93-e
Electronic Meeting, September 13 - 17, 2021

RP-212375

ZTE
Tomorrow never waits

Source: ZTE, Sanechips
Agenda: 9.0.2

Uplink Enhancements for 5G Advanced



Background

- All companies agree that “UL enhancement” can be considered as one of the key topics for Rel-18, according to the email discussion for RAN#93-e Rel-18 preparation summarized in RP-211652.
- It’s a common understanding that ‘UL enhancements’ includes both UL capacity enhancements and UL coverage enhancements.
- Below is the high-level description for “UL enhancements’ as summarized in RP-211652.

> - Study and if necessary specify >4 Tx UL operation, e.g., for CPE/FWA/vehicle/Industrial devices [leading WG: RAN1]
> - Specify enhanced multi-panel uplink operation and/or enhanced multi-TRP uplink operation, potentially including fast UL panel selection, separate UL timings/power controls for different panel/TRP and/or simultaneous multi-panel UL transmission [leading WG; RAN1]
> - Study and if necessary specify frequency-selective precoding, mainly targeting devices with >=4 Tx [leading WG: RAN1]
> - Specify further coverage enhancements including PRACH enhancement for FR2 e.g., PRACH repetition with same or different beams [leading WG: RAN1]
> - Study and if necessary specify power domain enhancements e.g., dynamic power aggregation [leading WG: RAN4 or RAN1]
> - Potentially specify other UL enhancements e.g., enhancement for multi-carrier UL operation, enhancements for DFTS-OFDM, enhancement for UL CW mapping [leading WG: RAN1]

Overall View

- UL MIMO Enhancements
  - >4 Tx operation (for both >4 layers and ≤ 4)
    - For CB, Type-I like UL CB as a starting point
    - For NCB, re-design of DCI SRI codepoint.
    - SRS/DMRS enh. for supporting 6 or 8 Tx
  - Enhanced multi-panel/multi-TRP uplink operation
    - Support simultaneous Tx cross multi panel
  - Frequency-selective precoding (for both CB and NCB)
    - Flexible signaling with tolerable DCI overhead.
  - UL CW mapping enhancement (for ≥ 2 layers).
    - CW mapping, and UCI multiplexing
    - CW-specific Tx power allocation

- UL Coverage Enhancements
  - Sequence based PUCCH for >2 bits UCI
    - New sequence generation
    - UCI to sequence mapping and sequence to RE mapping
  - Multiple PRACH transmissions
    - With the same or different beam
  - Power domain enhancements
    - Dynamic power aggregation for UL CA

Note 1: The red highlighted items have relatively high priority in our view.

Note 2: CA enhancements with flexible spectrum integration and UE aggregation are also beneficial for UL performance, and our detailed views for these two topics are provided in RP-212394 and RP-212399 respectively.

Note 3: Depending on the overall scope chosen from UL MIMO enhancements and UL coverage enhancements, including UL CA enhancements and/or UE aggregation under UL enhancements topic can also be considered.

General – How to distribute legacy MIMO objectives

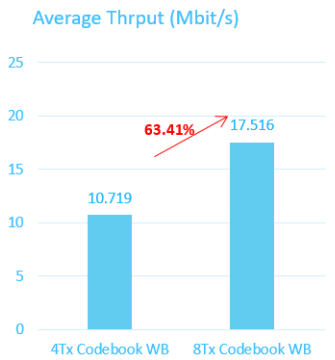
- There are overlaps among UL enhancements, DL-MIMO, and mobility as many companies raised during the June WS, since these above items are all relevant to legacy MIMO enh. in Rel-16/17.
  - To enable the new marker of 5G-Advanced 'UL enhancement', as well as balance TU(s) & scopes across several WID(s), we support to split legacy MIMO related objectives as follows:

- Regarding UL enhancement, UL-MIMO (involving UL only and both DL and UL) should be considered.
  - >4 Tx operation
  - Enhanced multi-panel/multi-TRP uplink operation
  - Frequency-selective precoding
  - UL CW mapping enhancement (for ≥ 2 layers).
- Regarding DL MIMO, DL-MIMO related aspects should be involved.
  - Further enhancements for CSI (e.g., URLLC CSI flexibility, etc.)
  - Evolved handling of multi-TRP (Transmission Reception Points) and multi-beam
  - CPE(customer premises equipment)-specific considerations
- Regarding mobility, L1-centric mobility related aspects should be involved.
  - Layer 1/layer 2 based inter cell mobility (mainly for Scenario-2 but also include left-over issues for Scenario-1)

UL MIMO Enhancements(1)

Item-1: >4 Tx operation on the following aspects, targeting both FR1 and FR2

- **Motivation:** To enable > 4 layer UL transmission, e.g., up to 8 layer for SU-MIMO, and up to 12 layers or more for MU-MIMO and UE-aggregation.
- **Objective:**
  - For CB, Type-I like UL codebook as a starting point (for both >4 layers and ≤ 4).
  - For NCB, re-design of DCI SRI codepoint (for both >4 layers and ≤ 4).
  - Increase of #. of DMRS ports per UE.
  - SRS design for supporting 6 or 8 Tx (e.g., for CB, NCB, and antenna switching (e.g., 6T6R, 6T8R, 8T8R)).



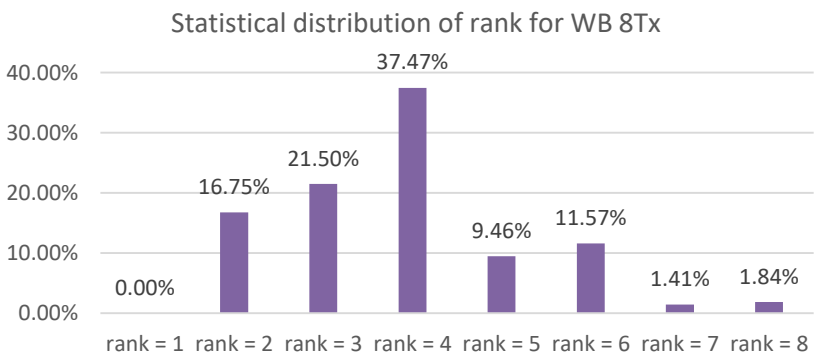
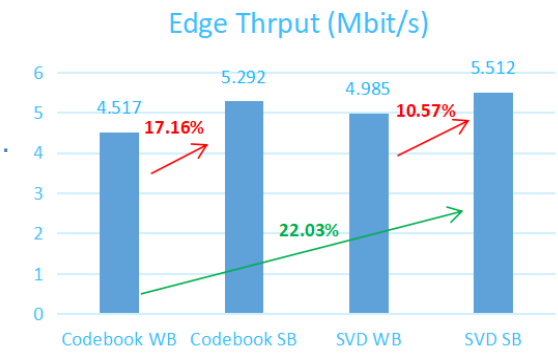


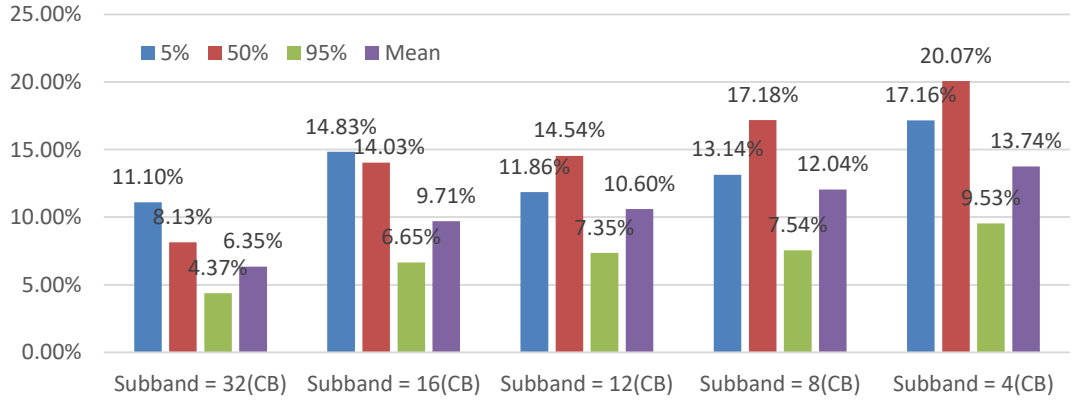
Figure 1 Mean UPT and rank distribution for WB 8Tx in indoor hotspot with 3.5GHz, 30KHz, 40MHz(100RB), 4-Tx, RANK adaption and full-buffer

UL MIMO Enhancements(2)

Item-2: Frequency-selective precoding on the following aspects, targeting both FR1 and FR2

- **Motivation:** To support high-performance transmission in larger UL BW
  - Significant gain for average & edge UPT (more efficient than WB high-res. only)
  - In terms of granularity, 16-RB subband @100RB can almost reach upper bound.
- **Objective:**
  - Flexible signaling design with tolerable increase of DCI overhead.
  - Above applies to both CB and NCB PUSCH transmission.





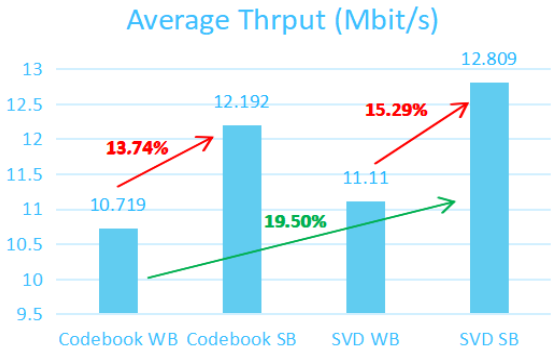


Figure 1 Performance gain as a function of precoding granularity, cell-edge UPT and average UPT in indoor hotspot with 3.5GHz, 30KHz, 40MHz(100RB), 4-Tx, RANK adaption and full-buffer

UL MIMO Enhancements(3)

Item-3: Enhanced multi-panel/multi-TRP uplink operation, targeting both FR1 and FR2

- **Motivation**: To further improve UL capacity (e.g., ~15.7% mean UPT for STxMP) and reliability via spatial multiplexing/diversity
- **Objective**:
  - High-priority: Support simultaneous Tx cross multi panel (e.g., FDM and SDM, PUSCH vs PUCCH)
    - Strive for unified signaling design for TD/SD/FD-repetition/multiplexing PUSCH (being compatible for Rel-17 mTRP PUSCH), and frequency selective indication.
    - Separate UL timings/power controls for different panel/TRP
  - Mid-priority: Enhancements on UL-only M-TRP operation (involving UL BM and power control).

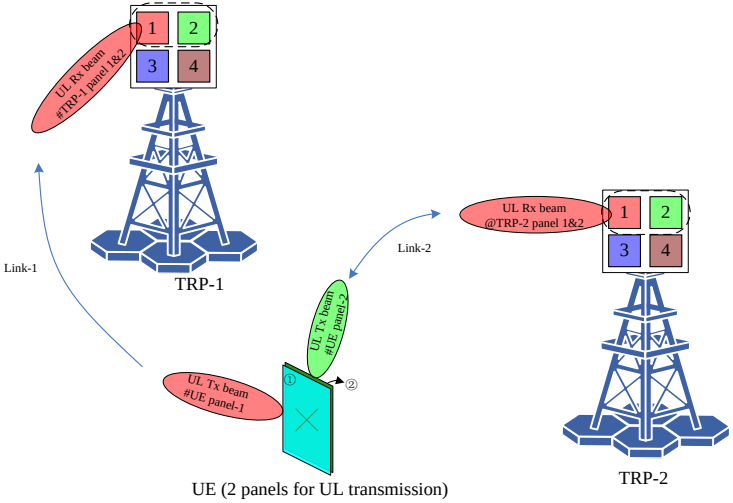
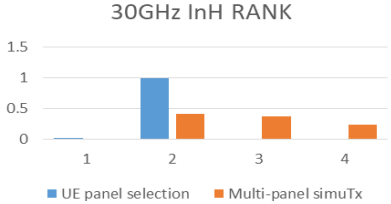


Figure 1 Scenario of multi-panel simultaneous transmission



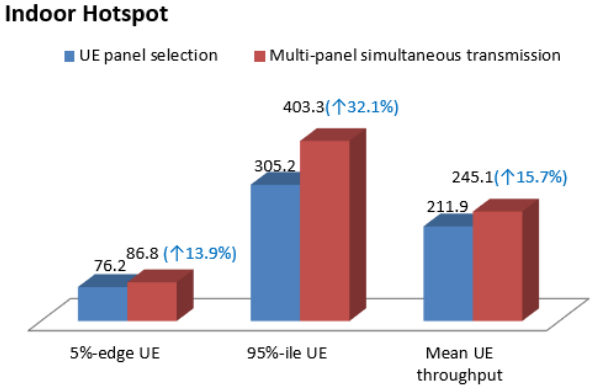


Figure 2 UPT performance of simultaneous transmission cross multi-panel (STxMP) in indoor hotspot, and the corresponding PDF as a function of RANK

UL MIMO Enhancements(4)

Item-4: UL codeword (CW) mapping enhancement, targeting both FR1 and FR2

- **Background**: The issue was observed from real tests, and the UL CW mapping enhancement for ≤ 4 layers was supported by many operators based on RAN1 Rel-17 TEI discussion.
- **Objective**: To support >1 CWs for both >4 layers and ≤ 4 in UL
  - CW mapping, and signaling design (e.g., per-CW MCS/NDI/RV indication)
  - UCI multiplexing, e.g., in one out of 2 codewords as in LTE

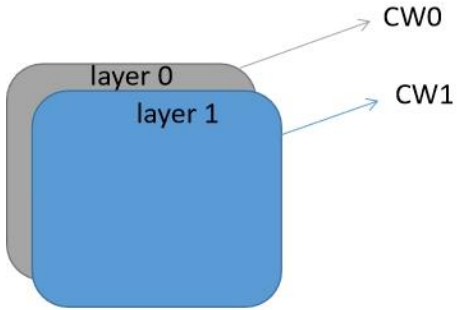
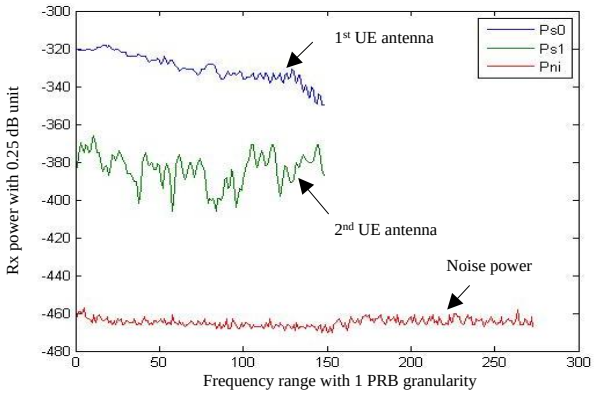


Figure 1 Examples of two separate CWs for different layers

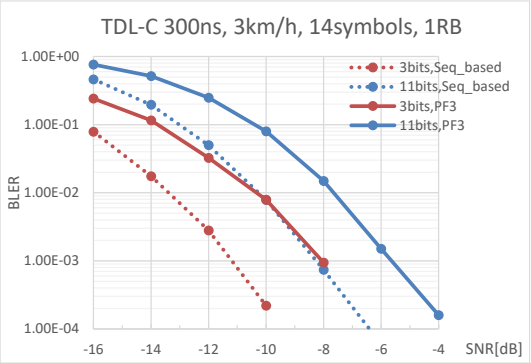


RU	Solution	Average UE-Throughput	5% UE-Throughput	50% UE-Throughput	95% UE-Throughput.
60%	One MCS/TB	15.91	3.61	11.83	42.21
	Two MCS/TB	20.65	4.45	16.68	54.82
	Gain	29.8%	23.1%	41.0%	29.9%
20%	One MCS/TB	37.52	10.62	31.37	76.30
	Two MCS/TB	41.15	14.17	36.00	76.30
	Gain	9.7%	33.5%	14.8%	0.0%

Figure 2 Real test results (left; Rx power gap between two layers is ~10 dB), and UPT (Mbps) with 9 dB average Rx power gap between two layers

UL Coverage Enhancements (1)

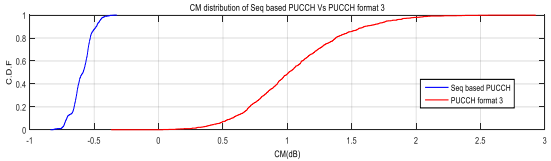
- UL MIMO enhancements are mainly for PUSCH, and enhancements to PUCCH and PRACH are desirable to match up PUSCH coverage.
- Enhancements with high priority:
  - Sequence based PUCCH for >2 bits UCI
  - Multiple PRACH transmissions
  - Power domain enhancements

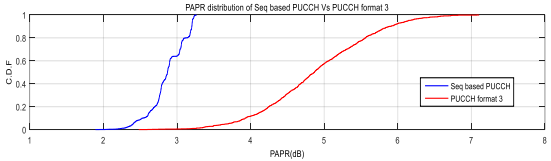


2~2.5 dB SNR gain

1) Sequence based PUCCH for more than 2bits

- **Motivation**
  - Large SNR gain
  - Large PAPR gain
  - Limited time with unaligned simulation assumptions in Rel-17 SI.
- **Objective:**
  - Focus on 3~11 bits
  - Potential new sequence generation
  - UCI to sequence mapping and sequence to RE mapping



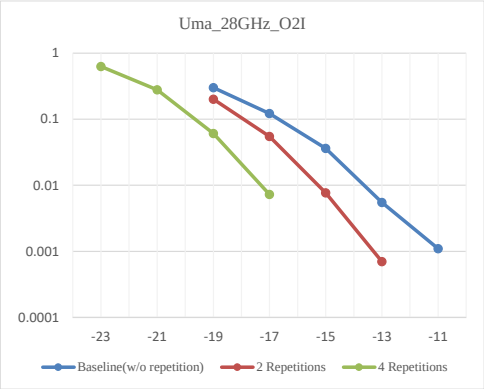


~2dB CM/PAPR gain @50th percentile

UL Coverage Enhancements (2)

2) Multiple PRACH transmissions

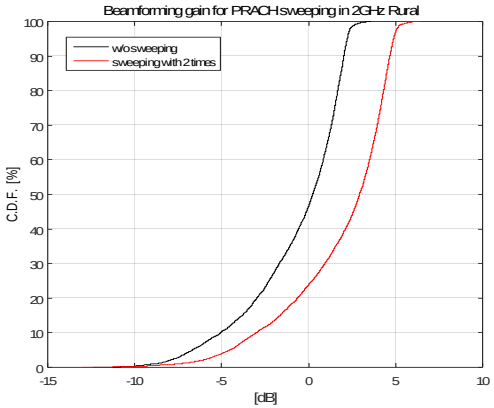
- **Motivation**
  - With the same beam, i.e., enabling PRACH repetition to increase the accumulated power.
  - With different beams, i.e., enjoying beam sweeping gain not only for PRACH but also subsequent UL channels in RACH procedure.
  - It is beneficial in terms of both coverage and latency.
- **Objective**
  - Triggering mechanism
  - Transmission pattern
  - Differentiation between enhanced UE and legacy UE



LLS shows about 2 dB gain by doubling the # of PRACH repetitions.

3) Power domain enhancements

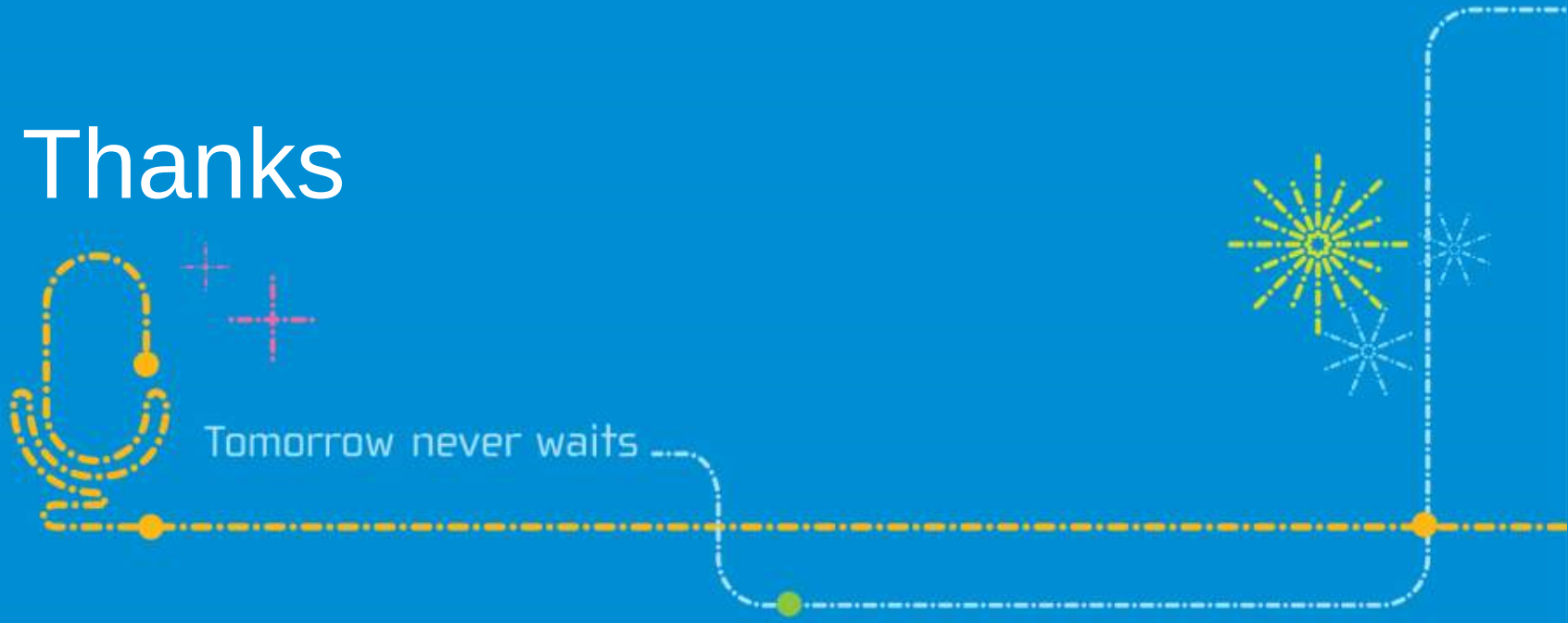
- **Motivation**
  - Under current SAR requirement, power aggregation in the time domain could directly improve UL performance for instant UL transmission.
  - Multi-band capable UE is able to support higher transmission power without RF design changes.
- **Objective**
  - Dynamic power aggregation for UL CA, including UL CA with Tx switching.



SLS shows about 2.5 dB gain by 2 PRACH beam sweeping.

Proposed objectives

Proposed objectives for UL enhancements:

- Specify >4 Tx UL operation, including UL CB enhancement, re-design of DCI SRI codepoint for NCB, increasing #. of DMRS ports per UE, and SRS design for supporting 6 or 8 Tx [RAN1].
- Specify enhanced multi-panel uplink operation and enhanced multi-TRP uplink operation, including separate UL timings/power controls for different panel/TRP, simultaneous multi-panel UL transmission, and UL-only M-TRP operation [RAN1].
- Study and, if necessary, specify frequency-selective precoding with flexible signaling design and tolerable increase of DCI overhead [RAN1].
- Specify >1 UL CW mapping for ≥ 2 layers, including signaling design (e.g., per-CW MCS/NDI/RV indication) and UCI multiplexing (e.g., in one out of 2 codewords) [RAN1].
- Study and, if necessary, specify power domain enhancements, e.g., dynamic power aggregation.
- Specify multiple PRACH transmissions with same or different beams [RAN1].
- Specify sequence based PUCCH for more than 2 bits UCI [RAN1].

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