Data Performance in 5G Industry use-cases

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INDUSTRIAL RADIO DAY
12. November 2025

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Contents

Performance verification for Data use-cases in 5G networks performance

Examples

- ► Scenario: UDP latency variation in relation to UE
- ► Scenario: low DL and UL data throughput
- ► Scenario: only UL data throughput is low

Test-device considerations in Industry networks

- Not every smartphone works in private networks (Network settings)
- Smartphones are limited for high Up-link data applications
- 5G modules represent the majoríty of industry applications

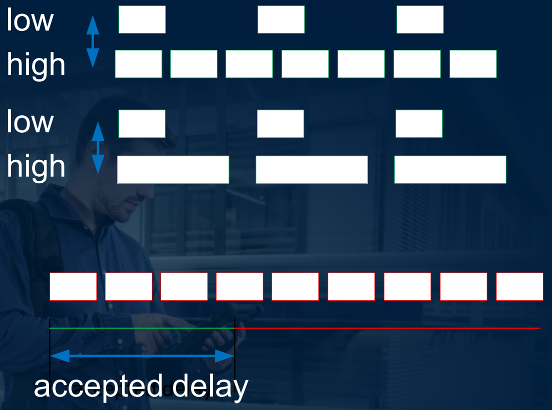



LATENCY MEASUREMENTS BASED ON UDP STREAM TEST
ENHANCEMENT TO INTERACTIVITY TEST

- ▶ Server streams packets as per defined parameters
- ▶ Direction (DL, UL or bidirectional) can be configured
- ▶ "I4.0 Watchdog" sending 100bytes every 50ms (16kbps)

LATENCY MEASUREMENTS BASED ON INTERACTIVITY TEST

- Control parameters (on technical level) are:
  - Packet rate
  - Packet size
  - Delay budget
    (…if exceeded, packet is counted as dropped / discarded)



ITU standardized method:
[ITU-T G.1051]

Data profile characteristics				
Profile	Packet size	Packet rate	Data rate	Delay Budget
Low	100 Bytes	8 ms	100 kbps	500 ms
Med	650 Bytes	5 ms	1 Mbps	500 ms
High	1450 Bytes	0.77 ms	15 Mbps	500 ms
Long	250 Bytes	6.67 ms	300 kbps	2000 ms
AGV Watchdog	100k Bytes	50 ms	16 kbps	50 ms
e-game realttime	100 Bytes	8 / 2.67 / 0.8 ms	0.1 / 0.3 / 1 Mbps	100 ms
Online meeting	1000 Bytes	16.1 / 4 ms	0.5 / 2 Mbps	300 ms

Todays Networks Latency Performance (Example)

Interactivity Test Summary View:1 QoS[1] <MV32-W-A[1]>

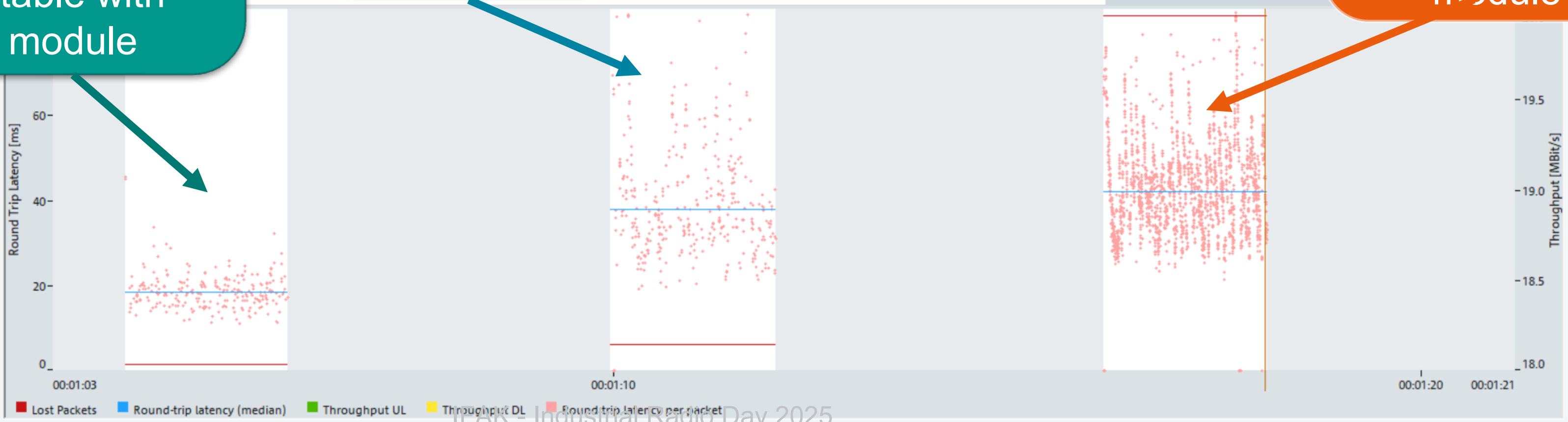
Job Index	Time St...	Time Stop	Pattern	Result	# Sent	# Lost	# Not sent	Disc. Ratio [%]	PLR [%]	PLR UL [%]	PLR DL [%]	Channel Qo...	RTT (median) [ms]	RTT (P10) [ms]	TT (max) [ms]	RT De...	PDV (median) [ms]	PDV UL (median) [ms]
5 - 1	00:01:02	00:01:05	Constant low	Ok	250	0	0	0.000	0.000	0.000	0.000	100.000	18.484	14.228	45.553	[illegible]	7.395	4.920
6 - 1	00:01:08	00:01:11	Constant me...	Ok	400	3	0	0.000	0.750	0.750	0.000	100.000	37.915	26 [illegible]	135.423	[illegible]	18.633	18.128
7 - 1	00:01:14	00:01:18	Constant high	Ok	2601	54	0	0.000	2.076	0.577	1.499	96.333	42.197	30.487	191.477	[illegible]	20.746	11.249

One of the most important KPIs in private networks optimized for URLLC

Low (100kpbs) RTT = ~ 18.5ms versus 12ms stable with module

Med (1Mpbs) RTT = ~ 38ms versus 19ms stable with module

High (15Mpbs) RTT = ~ 42ms versus 19 ms stable with module

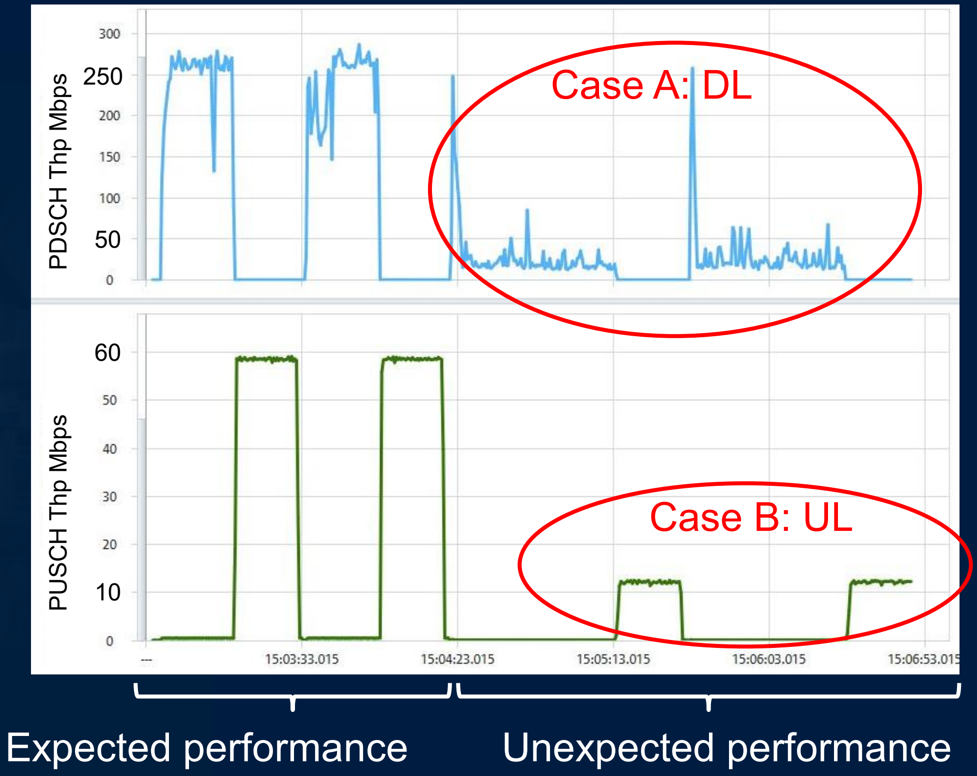


Scenario - Throughput DL and UL lower than expected

- Alternating DL and UL data sessions (iPerf3)
- Expected DL Thp: ~ 300 Mbps
- Expected UL Thp: ~ 60 Mbps

- What is the root cause for low data throughput?

▶ Let's do troubleshooting!



Troubleshooting

RSRP: Reference Signal Received Power
SINR: Signal to Interference and Noise Ratio
TTI: Transmission Time Interval
MCS: Modulation and Coding Scheme
HARQ: Hybrid Automatic Repeat request
CQI: Channel Quality Indicator

Questions:

- Why the DL throughput is lower than expected?
- Why the UL throughput is lower than expected?

<u>The troubleshooter's recipe:</u>

1. Check the DL RF situation: SSB RSRP and SINR, CSI-RS CQI
2. UE capabilities suitable?
3. Check MCS statistics in both DL and UL direction
4. Check the Transmission statistics
5. Further drill-down into TTI-based transmission: Check the HARQ process
6. Interpretation

▶ Let's take the measurement file and troubleshoot step-by-step!

Why DL throughput is lower than expected?

1. Check the DL RF situation (RSRP, SINR)

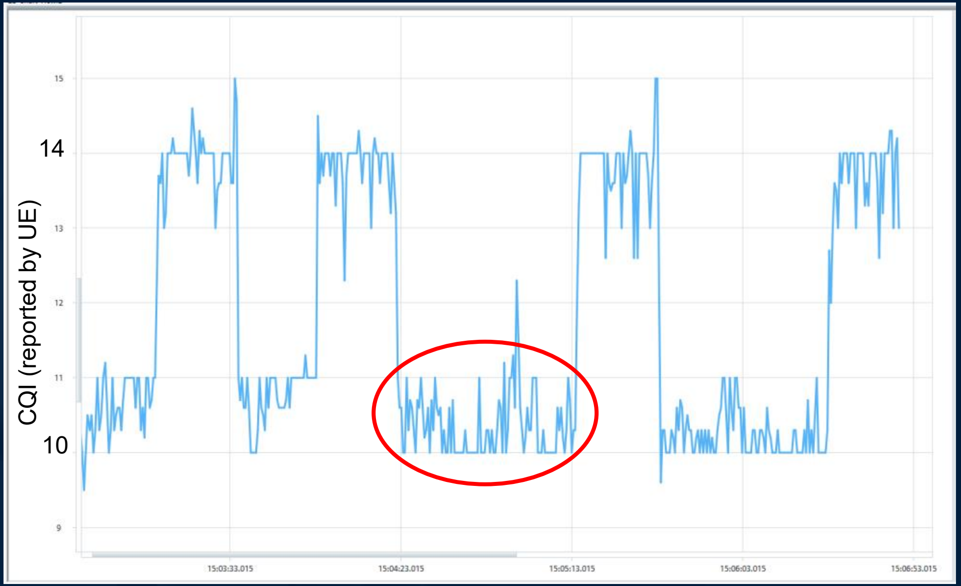
- SSB measurement:
  DL RSRP (~ -60 dBm)
  and SINR (~ 35 dB)
  are very good!

- By scanner as neutral instance

- There is no interference in DL direction (would be visible in SINR)!

Why DL throughput is lower than expected?

1. Check the DL RF situation (CSI-RS CQI)



- UE reports CQI 10…11 during the DL session (proposal for the basestation → 64 QAM)

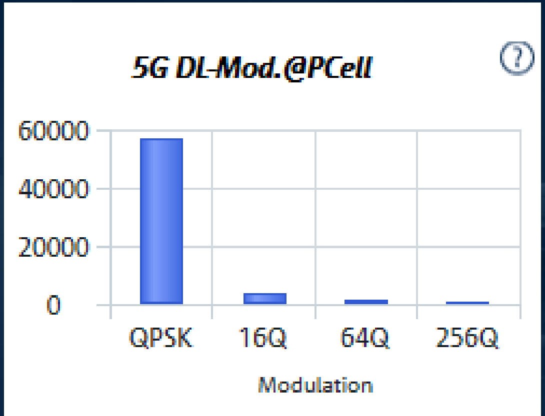
CQI index	modulation	code rate x 1024	efficiency
0	out of range		
1	QPSK	78	0.1523
2	QPSK	193	0.3770
3	QPSK	449	0.8770
4	16QAM	378	1.4766
5	16QAM	490	1.9141
6	16QAM	616	2.4063
7	64QAM	466	2.7305
8	64QAM	567	3.3223
9	64QAM	666	3.9023
10	64QAM	772	4.5234
11	64QAM	873	5.1152
12	256QAM	711	5.5547
13	256QAM	797	6.2266
14	256QAM	885	6.9141
15	256QAM	948	7.4063

- There is no interference in DL direction (CQI reported by UE would be lower)!

Why DL throughput is lower than expected?

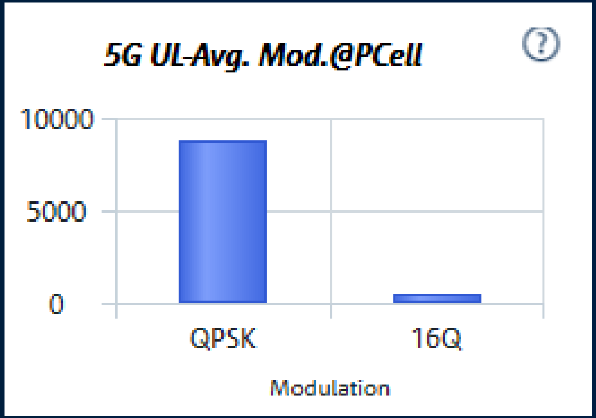
2. Check MCS statistics in both DL and UL direction

DL data session:



▶ QPSK is mostly used for DL traffic

UL data session:

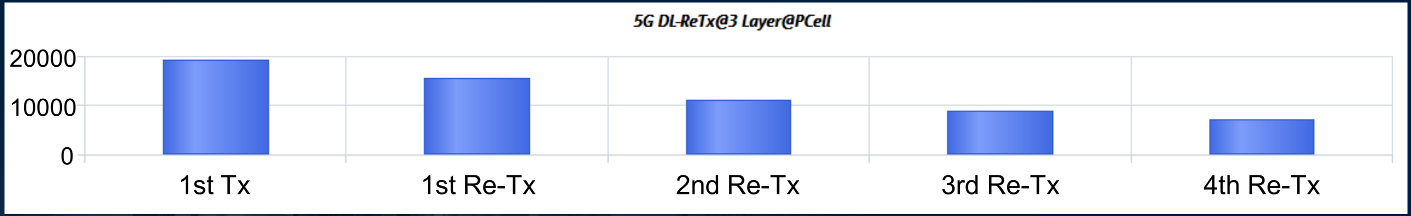


▶ QPSK is mostly used for UL traffic

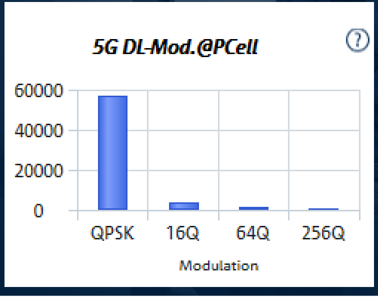
▶ DL RSRP and SINR are good but only QPSK used for DL and UL traffic

Why DL throughput is lower than expected?

3. Check the DL Transmission statistics



DL data session



- BS aims typically at 10% Re-Tx to maximize throughput
- 1/3 of all samples are 1st transmissions
- 2/3 of all samples are re-transmissions
  → far higher than the typical 10% Re-Tx target

- Why was no acknowledgement received at the BS?

Why DL throughput is lower than expected?

4. Deep dive into TTI-based transmission: Check the HARQ process

5G NR TTI View RM520N-GL[1]

Source	SFN	Slot	HARQ	MCS	Mod	CRC	ReTx	RV
pdsch			13					
PDSCH	840	13	13	14	64Q	PASS	0	0
PDSCH	841	7	13	14	64Q	PASS	1	2
PDSCH	842	2	13	14	64Q	PASS	2	3
PDSCH	842	16	13	14	64Q	PASS	3	1
PDSCH	843	15	13	14	64Q	PASS	4	0
PDSCH	845	6	13	14	64Q	PASS	0	0
PDSCH	846	2	13	14	64Q	PASS	1	2
PDSCH	847	1	13	14	64Q	PASS	2	3
PDSCH	847	16	13	14	64Q	PASS	3	1
PDSCH	848	18	13	11	64Q	PASS	0	0
PDSCH	849	16	13	11	64Q	PASS	1	2
PDSCH	851	8	13	10	16Q	PASS	0	0
PDSCH	852	1	13	10	16Q	PASS	1	2
PDSCH	853	2	13	10	16Q	PASS	2	3
PDSCH	853	18	13	10	16Q	PASS	3	1
PDSCH	854	17	13	10	16Q	PASS	4	0
PDSCH	858	0	13	8	16Q	PASS	0	0
PDSCH	858	17	13	8	16Q	PASS	1	2
PDSCH	859	12	13	8	16Q	PASS	2	3
PDSCH	860	6	13	8	16Q	PASS	3	1
PDSCH	861	1	13	8	16Q	PASS	4	0

- Filter data to 1 HARQ process (e.g. HARQ 13)
- 1st DL message (slot 13): UE passes the DL CRC, but BS re-transmits the same HARQ (MCS 14 = 64QAM)
- 1st Re-Tx (slot 7): UE passes the DL CRC, but BS re-transmits again the same HARQ
- 2nd Re-Tx (slot 2): UE passes the DL CRC, but BS re-transmits again the same HARQ
- And a third (slot 16) and a fourth (slot 15)
- BS continuously reduces the MCS in DL to transmit more robust and cuts down the data throughput

▶ DL transmission is ok, but BS does not receive the Ack in UL → many unnecessary re-tx!

▶ The problem must be in the UL direction!

CRC: Cyclic Redundancy Check

Why DL throughput is lower than expected?

5. Interpretation

Summing up all results:

- No interference in DL direction!
- MCS is bad = data throughput is bad
- Many re-transmissions
- Re-transmissions are not necessary (CRC passed), but Ack were not received
- UL has a radio problem!

→ Unwanted power received by BS that only affects UL but not DL slots
→ Another BS transmits at the wrong time → non-synchronized networks!

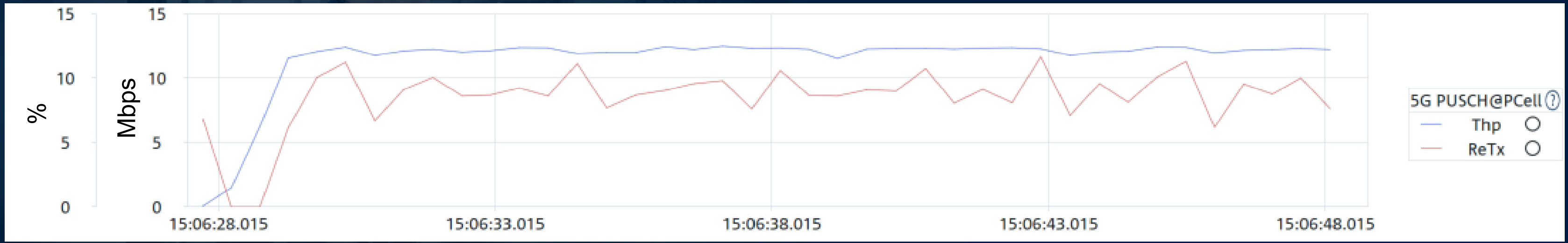
CRC: Cyclic Redundancy Check

Why UL throughput is lower than expected?

1. Check the RF situation (RSRP, SINR): we know, DL RF is good

2. Check MCS statistics in both DL and UL direction: we know, MCS in UL is bad

3. Check the Re-Transmission statistics

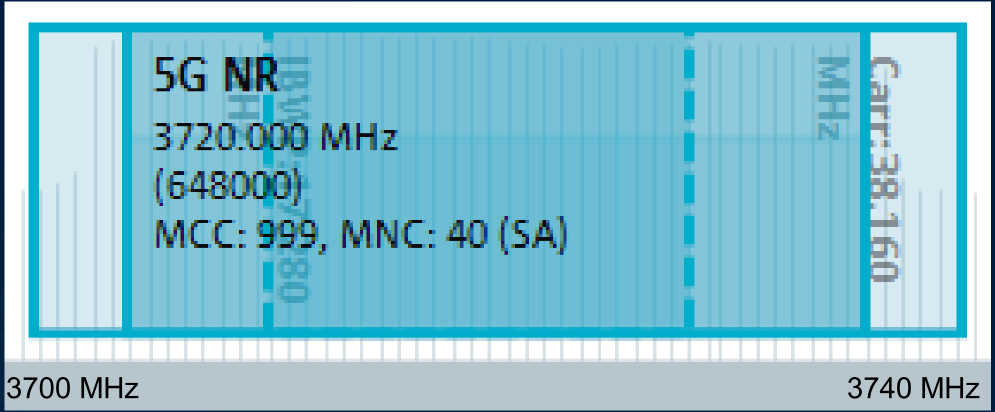


~ 10% Re-Transmission rate is a typical target of BS scheduler balancing throughput and reliability

4. Interpretation: UL radio problem as before

5G network configuration -

- Private 5G network in band n78
- 40 MHz bandwidth, 30kHz SCS
- 3700 – 3740 MHz
- Networks synchronized
- Configured for more UL capacity:
  TDD pattern: DDDFUU DFUU



Radio frame 10 ms

Periodicity 5 ms

slot 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
DL	DL	DL	F	UL	UL	DL	F	UL	UL	DL	DL	DL	F	UL	UL	DL	F	UL	UL

- 20 slots per radio frame

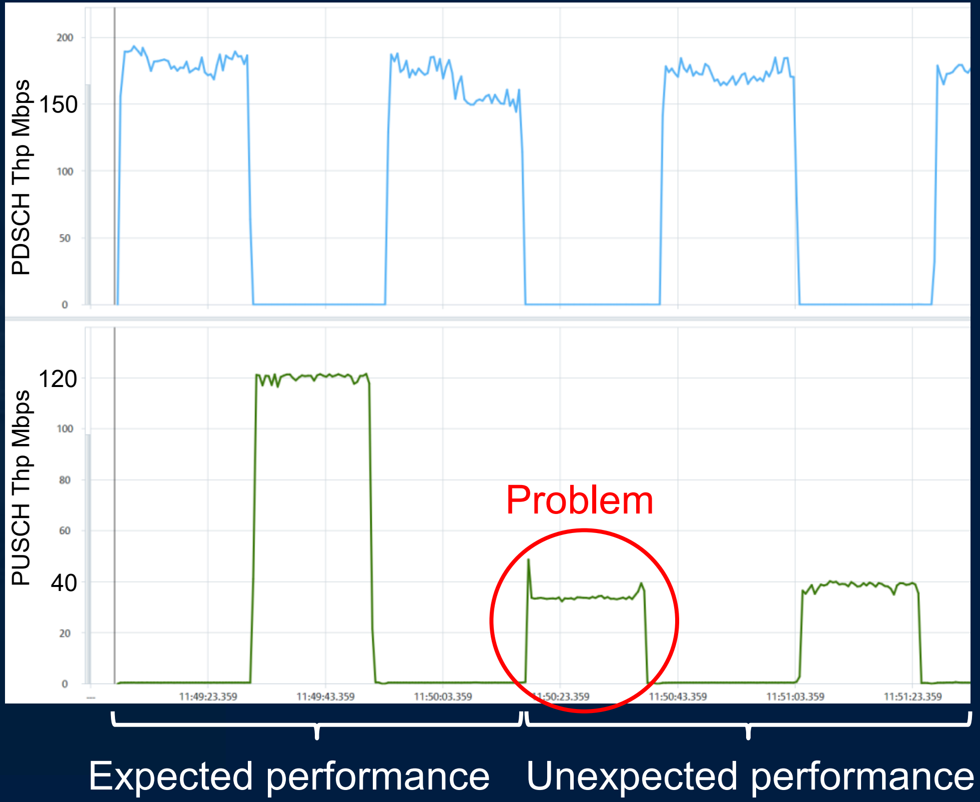
SCS: SubCarrier Spacing

UL data throughput lower than expected

- Alternating DL and UL data sessions (iPerf3)
- Expected UL Thp: ~ 120 Mbps

- What is the root cause for low data throughput?

▶ Let’s do troubleshooting!



Troubleshooting - the manual process by an expert

Questions:

- DL throughput is ok.
  Why is the UL throughput lower than expected?

The troubleshooter's recipe:

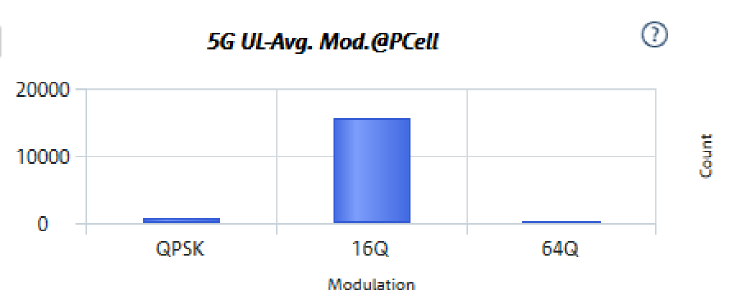
1. Check the RF situation (RSRP, SINR)
2. Check MCS statistics
3. Check the timeslot-based statistics
4. Further drill-down into TTI-based transmission
5. Analyze timeslot-based transmission fails
6. Interpretation

▶ Let's take the measurement file and troubleshoot step-by-step!

RSRP: Reference Signal Received Power
SINR: Signal to Interference and Noise Ratio
TTI: Transmission Time Interval
MCS: Modulation and Coding Scheme
HARQ: Hybrid Automatic Repeat reQuest

Why UL throughput is lower than expected?

2. Check MCS statistics in UL direction



- 16QAM for most samples is not optimal (lower than expected)

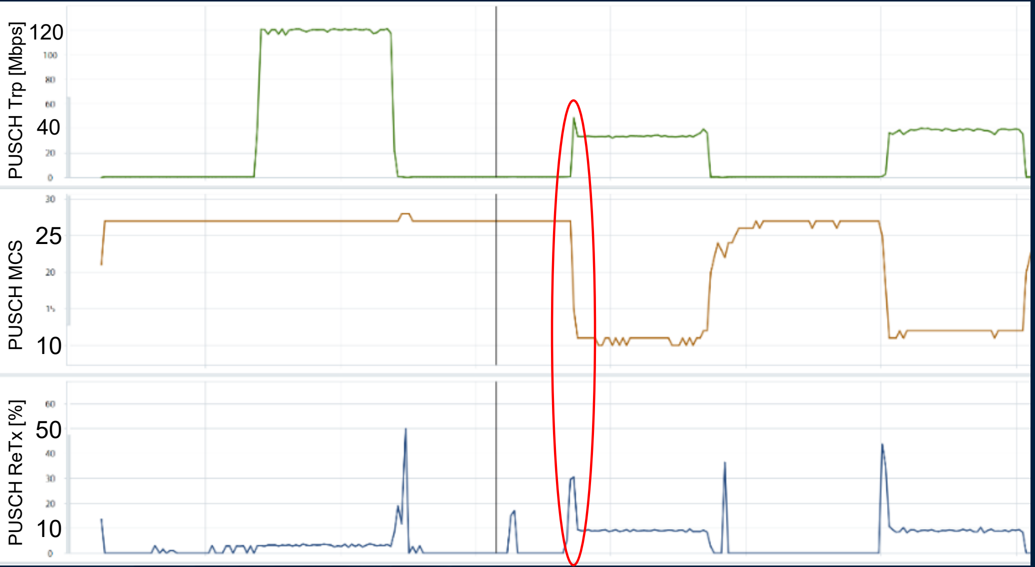
3. Check the timeslot-based UL transmission statistics:

Number of transmissions per timeslot

- All UL slots are equally used for transmission

Case C: Why UL throughput is lower than expected?

4. Further drill-down into TTI-based transmission:



- Relation between DL throughput, MCS and ReTx rate
- ReTx rate high
- BS scheduler adapts ReTx rate down to 10% by reducing MCS
  - From 27 down to 11
- UL throughput is lower

→ Check TTI-based transmission

Case C: Why UL throughput is lower than expected?

4. Further drill-down into TTI-based transmission:

5G NR TTI View RM520N-GL[1]

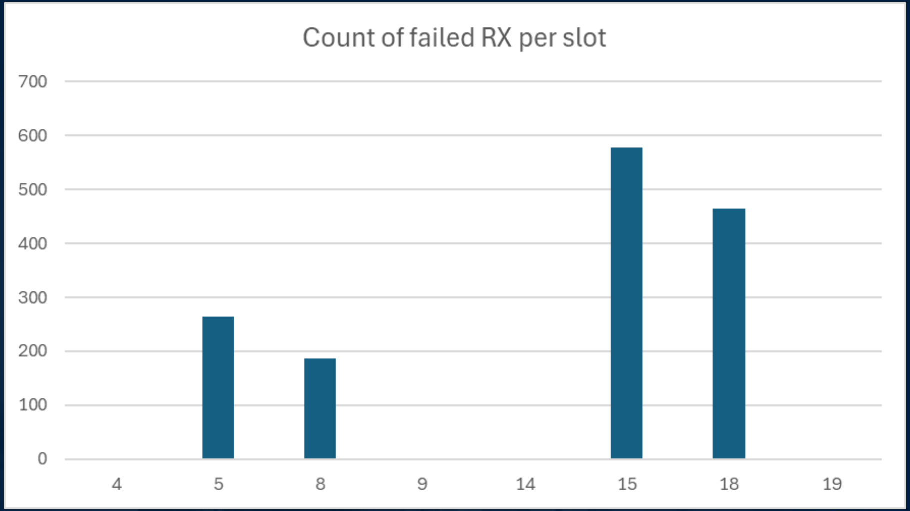
	Time	Dev. Time	Source	SFN	Slot	HARQ	MCS	Mod	TBS	RB	ReTx	RV
			pusch			13						
2314	11:51:03.5...	08:37:13.5...	PUSCH	560	14	13	27	64Q	832	4	New	0
2315	11:51:03.5...	08:37:13.7...	PUSCH	583	15	13	28	64Q	864	4	New	0
2316	11:51:03.562	08:37:13.8...	PUSCH	584	4	13	28	64Q	864	4	ReTx	2
2317	11:51:03.5...	08:37:13.8...	PUSCH	584	15	13	28	64Q	864	4	ReTx	3
2318	11:51:03.5...	08:37:13.8...	PUSCH	585	4	13	28	64Q	864	4	ReTx	1
2319	11:51:03.5...	08:37:13.8...	PUSCH	585	14	13	28	64Q	864	4	ReTx	0
2320	11:51:03.5...	08:37:14.0...	PUSCH	605	18	13	19	64Q	478	4	New	0
2321	11:51:03.5...	08:37:14.0...	PUSCH	606	4	13	19	64Q	478	4	ReTx	2
2322	11:51:04.0...	08:37:14.2...	PUSCH	629	18	13	15	16Q	372	4	New	0
2323	11:51:04.0...	08:37:14.2...	PUSCH	630	4	13	15	16Q	372	4	ReTx	2
2324	11:51:04.0...	08:37:14.4...	PUSCH	651	15	13	25	64Q	560	3	New	0
2325	11:51:04.0...	08:37:14.4...	PUSCH	652	4	13	25	64Q	560	3	ReTx	2
2326	11:51:04.0...	08:37:14.4...	PUSCH	652	14	13	25	64Q	560	3	ReTx	3
2327	11:51:04.5...	08:37:14.5...	PUSCH	660	8	13	16	16Q	8961	90	New	0
2328	11:51:04.5...	08:37:14.5...	PUSCH	660	15	13	16	16Q	8961	90	ReTx	2
2329	11:51:04.5...	08:37:14.5...	PUSCH	663	9	13	13	16Q	6661	90	New	0
2330	11:51:04.5...	08:37:14.6...	PUSCH	665	15	13	13	16Q	6661	90	New	0
2331	11:51:04.5...	08:37:14.6...	PUSCH	667	15	13	14	16Q	7557	90	New	0
2332	11:51:04.5...	08:37:14.6...	PUSCH	668	4	13	14	16Q	7557	90	ReTx	2
2333	11:51:04.5...	08:37:14.6...	PUSCH	670	5	13	12	16Q	5889	90	New	0
2334	11:51:04.5...	08:37:14.6...	PUSCH	672	8	13	14	16Q	7557	90	New	0
2335	11:51:04.5...	08:37:14.6...	PUSCH	672	15	13	14	16Q	7557	90	ReTx	2
2336	11:51:04.5...	08:37:14.7...	PUSCH	674	14	13	11	16Q	5122	90	New	0

- Filter data to 1 HARQ process (13)
- Many Re-transmissions initially
- Then MCS is reduced in consecutive TTIs
  - From 28 down to 11
- Resulting in fewer Re-transmissions
  - ~ 10% ReTx rate
- Some timeslots fail more than others

→ Check timeslot-specific behavior in UL direction

Case C: Why UL throughput is lower than expected?

5. Analyze timeslot-based transmission fails:



- UL transmission always fails on slots 5 / 15 and 8 / 18
- No failures on slots 4 / 14 and 9 / 19
- 1500 fails = # of re-transmissions (10% of all)

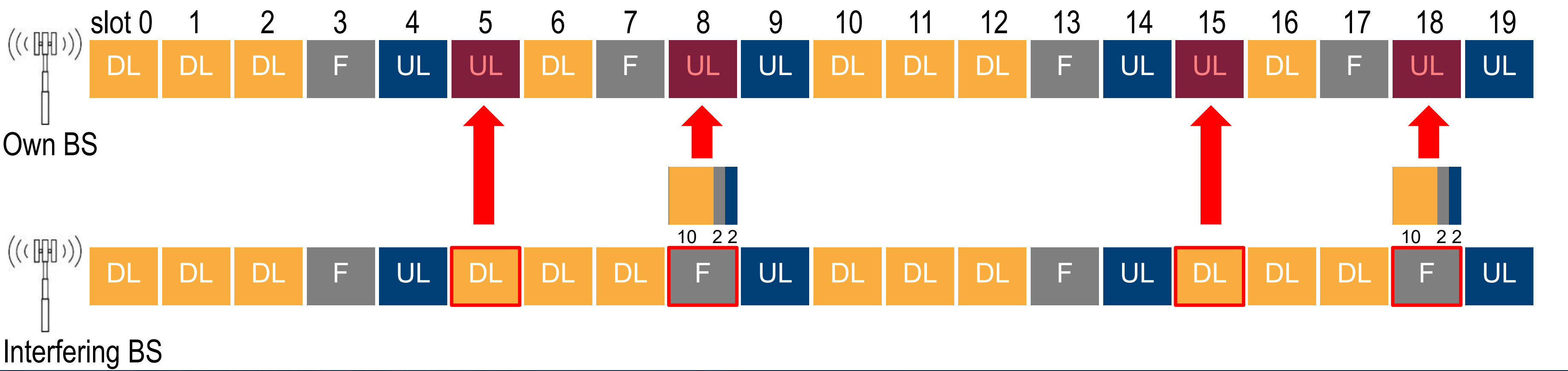
→ Clear timeslot dependency

→ Clear timeslot-dependent interference

Case C: Why UL throughput is lower than expected?

6. Interpretation:

▶ Clear timeslot-dependent interference



→ Another BS transmits at the wrong time → using a different TDD DL/UL pattern!

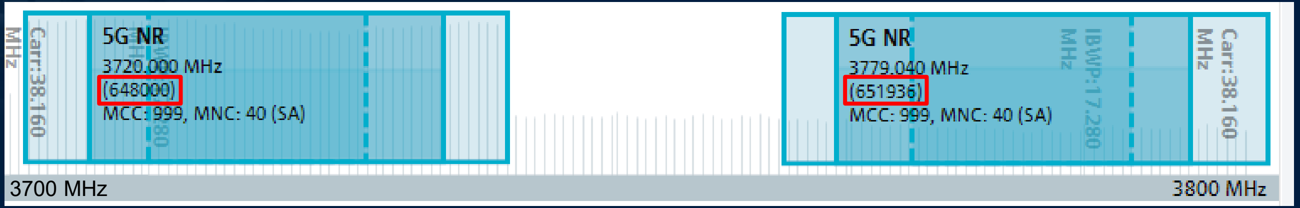
Passive Receiver detects without subscription different TDD pattern

- Network scanner (passive testing) receives all signals in the configured bands.

NR-ARFCN	SS-Ref	MCC	MNC	TDD Pattern	TDD Pattern(full)
648000	3720.00	999	40	DDDFUU (3 ms) | DFUU (2 ms)	D3-d6-f4u4-U2 D1-d10-f4-U2
651936	3779.04	999	40	DDDFU (2.5 ms)	D3-d10-f2u2-U1

- ➢ Two carriers in the same band use different TDD DL/UL patterns
- ➢ DL slots of ARFCN 651936 interfere with UL slots 5, 8, 15, 18 of 648000

➢ Automatic Channel Detection (ACD) visualizes the carriers



Summary

Selection of active testing sensors are important for dedicated performance tests

Non-synchronized networks can cause UL interference

Intermodulation can cause interference in neighboring frequency carriers

Questions ?