

ROMES Insight and TTI-View to verify Root Causes for Bad Throughput

PDCP Downlink “out of window” – Meaning of Dropped OOW

What “Dropped OOW” Means:

Dropped OOW (Out Of Window) refers to a PDCP-layer discard event defined in 3GPP TS 38.323.

A PDCP PDU is dropped as Out-Of-Window when:

Its PDCP sequence number (SN) falls outside the current PDCP reordering window at the receiver.

This typically happens when:

- PDCP packets arrive too late
- PDCP packets arrive too far ahead
- PDCP reordering timer expires
- Excessive out-of-order delivery occurs between multiple radio legs

Once a PDCP PDU is OOW:

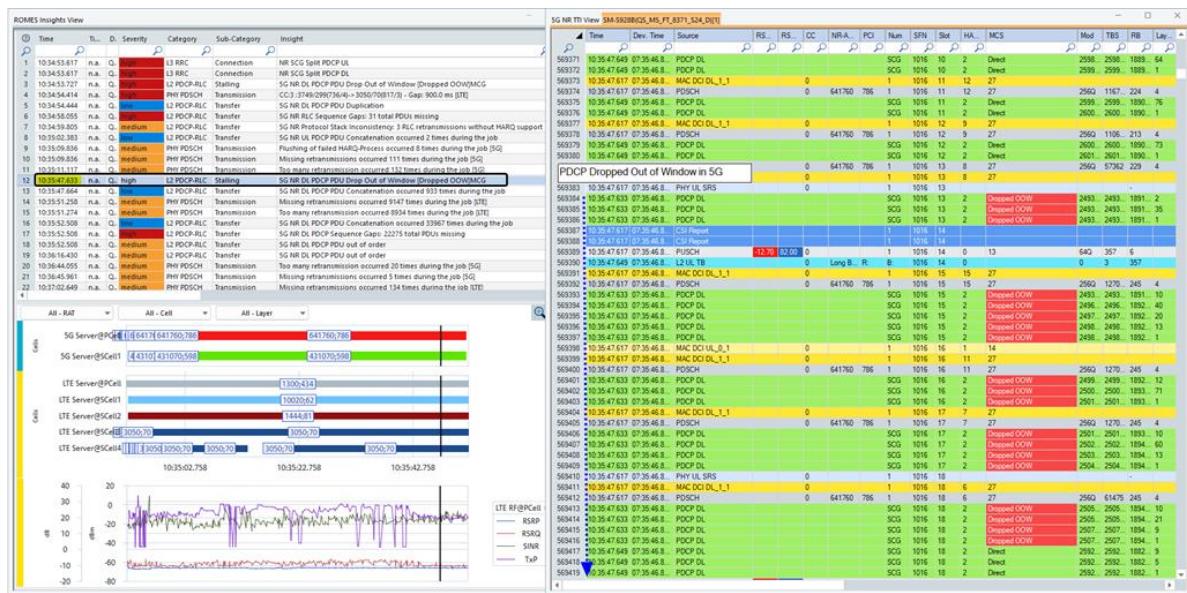
- It will not be delivered to upper layers
- It is not retransmitted
- The loss is permanent and visible to TCP as packet loss

PDCP maintains a reordering window defined by the PDCP sequence numbers (SNs). Each PDCP PDU (data packet) carries a PDCP SN (e.g., 12-bit or 18-bit depending on configuration).

For very high throughput > 500 Mbit/s, the 18 bit SN-Length is a must!

The window defines the range of PDCP SNs that are considered “valid” or “expected” at a given time.

If a PDCP PDU arrives with an SN smaller than the lower edge of the window (too old) or larger than the upper edge (too far in the future), the QC-Chip/Device (info is picked up by ROMES) flags it as “out of window”. These packets are dropped because PDCP can't correctly reorder or deliver them.



Example: PDCP Dropped OOW both in NR and LTE

The below example shows a lot of PDCP Dropped OOW both in NR and LTE. This ring the alarm to the gNB PDCP Flow Control on X2-Interface.

However the number of Bytes Dropped Out of Window must be counted to determine if it represents a serious threat for the throughput over air because:

the number of PDCP DL Packets Dropped OOW have to be sent over the air-interface and thus is a waste of time and reduces thus reduces the overall Throughput:

Note:

MCG = LTE Master Cell Group, SCG = NR Secondary Cell Group

| Time | Dev. | Time | Source | R | R | C | N | P | Path | SFN | Stn | RB I... | State | Start | Stop | RLC SN | #IP Packets | #IP Bytes | Rx Deliv | Rx Next | Next Cnt | PDCP Start Cnt | PDCP Stop Cnt |
|------|--------------|---------------|---------|-----|------|----|---|---|-------------|--------|--------|---------|-------|-------|------|--------|-------------|-----------|----------|---------|----------|----------------|---------------|
| 40 | 10:34:53.727 | 07:34:52.9... | PDCP DL | MCG | 747 | 9 | 2 | | Dropped OOW | 7019 | 7019 | 108 | 1 | 1500 | | | | | | | 7019 | 7019 | |
| 41 | 10:34:53.727 | 07:34:52.9... | PDCP DL | MCG | 748 | 0 | 2 | | Dropped OOW | 7020 | 7020 | 110 | 8 | 12000 | | | | | | | 7020 | 7020 | |
| 42 | 10:34:53.727 | 07:34:52.9... | PDCP DL | MCG | 748 | 0 | 2 | | Dropped OOW | 7028 | 7028 | 111 | 1 | 1500 | | | | | | | 7028 | 7028 | |
| 43 | 10:34:53.727 | 07:34:52.9... | PDCP DL | MCG | 748 | 8 | 2 | | Dropped OOW | 7029 | 7029 | 111 | 4 | 6000 | | | | | | | 7029 | 7029 | |
| 44 | 10:34:53.727 | 07:34:52.9... | PDCP DL | MCG | 749 | 8 | 2 | | Dropped OOW | 7033 | 7033 | 112 | 1 | 1500 | | | | | | | 7033 | 7033 | |
| 45 | 10:34:53.789 | 07:34:53.0... | PDCP DL | MCG | 749 | 8 | 2 | | Dropped OOW | 6901 | 6901 | 75 | 1 | 1500 | | | | | | | 6901 | 6901 | |
| 46 | 10:34:53.789 | 07:34:53.0... | PDCP DL | MCG | 749 | 8 | 2 | | Dropped OOW | 6902 | 6902 | 76 | 1 | 1500 | | | | | | | 6902 | 6902 | |
| 47 | 10:34:53.789 | 07:34:53.0... | PDCP DL | MCG | 751 | 3 | 2 | | Dropped OOW | 6903 | 6903 | 76 | 2 | 3000 | | | | | | | 6903 | 6903 | |
| 48 | 10:34:53.789 | 07:34:53.0... | PDCP DL | MCG | 753 | 3 | 2 | | Dropped OOW | 6905 | 6905 | 77 | 1 | 1500 | | | | | | | 6905 | 6905 | |
| 49 | 10:34:53.914 | 07:34:53.1... | PDCP DL | SCG | 761 | 0 | 2 | | Dropped OOW | 8014 | 8014 | 100 | 1 | 1500 | | | | | | | 8014 | 8014 | |
| 50 | 10:34:53.914 | 07:34:53.1... | PDCP DL | SCG | 765 | 5 | 2 | | Dropped OOW | 8015 | 8015 | 101 | 1 | 1500 | | | | | | | 8015 | 8015 | |
| 51 | 10:34:53.914 | 07:34:53.1... | PDCP DL | SCG | 765 | 5 | 2 | | Dropped OOW | 8015 | 8015 | 102 | 1 | 1500 | | | | | | | 8015 | 8015 | |
| 52 | 10:34:56.617 | 07:34:55.8... | PDCP DL | SCG | 1021 | 1 | 2 | | Dropped OOW | 227591 | 227591 | 159573 | 1 | 1500 | | | | | | | 227591 | 227591 | |
| 53 | 10:34:56.617 | 07:34:55.8... | PDCP DL | SCG | 5 | 8 | 2 | | Dropped OOW | 227714 | 227714 | 995 | 1 | 1500 | | | | | | | 227714 | 227714 | |
| 54 | 10:34:56.617 | 07:34:55.8... | PDCP DL | SCG | 6 | 3 | 2 | | Dropped OOW | 227840 | 227840 | 1016 | 1 | 1500 | | | | | | | 227840 | 227840 | |
| 55 | 10:34:56.617 | 07:34:55.8... | PDCP DL | SCG | 6 | 4 | 2 | | Dropped OOW | 227862 | 227862 | 0 | 1 | 1500 | | | | | | | 227862 | 227862 | |
| 56 | 10:34:56.617 | 07:34:55.8... | PDCP DL | SCG | 6 | 4 | 2 | | Dropped OOW | 227852 | 227852 | 1020 | 1 | 1500 | | | | | | | 227852 | 227852 | |
| 57 | 10:34:56.617 | 07:34:55.8... | PDCP DL | SCG | 6 | 5 | 2 | | Dropped OOW | 227877 | 227877 | 5 | 1 | 1500 | | | | | | | 227877 | 227877 | |
| 58 | 10:34:56.664 | 07:34:55.8... | PDCP DL | SCG | 6 | 5 | 2 | | Dropped OOW | 227886 | 227886 | 7 | 1 | 1500 | | | | | | | 227886 | 227886 | |
| 59 | 10:34:56.617 | 07:34:55.8... | PDCP DL | SCG | 9 | 3 | 2 | | Dropped OOW | 228281 | 228281 | 90 | 1 | 1500 | | | | | | | 228281 | 228281 | |
| 60 | 10:34:56.617 | 07:34:55.8... | PDCP DL | SCG | 10 | 2 | 2 | | Dropped OOW | 228468 | 228468 | 143 | 1 | 1500 | | | | | | | 228468 | 228468 | |
| 61 | 10:34:56.617 | 07:34:55.8... | PDCP DL | SCG | 10 | 5 | 2 | | Dropped OOW | 228493 | 228493 | 152 | 1 | 1500 | | | | | | | 228493 | 228493 | |
| 62 | 10:34:56.617 | 07:34:55.8... | PDCP DL | SCG | 10 | 5 | 2 | | Dropped OOW | 228500 | 228500 | 154 | 1 | 1500 | | | | | | | 228500 | 228500 | |
| 63 | 10:34:56.617 | 07:34:55.8... | PDCP DL | SCG | 10 | 6 | 2 | | Dropped OOW | 228516 | 228516 | 159 | 1 | 1500 | | | | | | | 228516 | 228516 | |
| 64 | 10:34:56.617 | 07:34:55.8... | PDCP DL | SCG | 10 | 7 | 2 | | Dropped OOW | 228536 | 228536 | 165 | 1 | 1500 | | | | | | | 228536 | 228536 | |
| 65 | 10:34:56.617 | 07:34:55.8... | PDCP DL | SCG | 10 | 15 | 2 | | Dropped OOW | 228536 | 228536 | 171 | 1 | 1500 | | | | | | | 228536 | 228536 | |
| 66 | 10:34:56.617 | 07:34:55.8... | PDCP DL | SCG | 10 | 15 | 2 | | Dropped OOW | 227709 | 227709 | 166021 | 1 | 1500 | | | | | | | 227709 | 227709 | |
| 67 | 10:34:56.617 | 07:34:55.8... | PDCP DL | SCG | 10 | 16 | 2 | | Dropped OOW | 227740 | 227740 | 166236 | 15 | 2300 | | | | | | | 227740 | 227740 | |
| 68 | 10:34:56.617 | 07:34:55.8... | PDCP DL | SCG | 11 | 0 | 2 | | Dropped OOW | 228102 | 228102 | 165249 | 1 | 1500 | | | | | | | 228102 | 228102 | |
| 69 | 10:34:56.617 | 07:34:55.8... | PDCP DL | SCG | 11 | 0 | 2 | | Dropped OOW | 228282 | 228282 | 90 | 2 | 3000 | | | | | | | 228282 | 228282 | |
| 70 | 10:34:56.617 | 07:34:55.8... | PDCP DL | SCG | 11 | 0 | 2 | | Dropped OOW | 228284 | 228284 | 91 | 1 | 1500 | | | | | | | 228284 | 228284 | |
| 71 | 10:34:56.617 | 07:34:55.8... | PDCP DL | SCG | 11 | 0 | 2 | | Dropped OOW | 228469 | 228469 | 143 | 2 | 3000 | | | | | | | 228469 | 228469 | |
| 72 | 10:34:56.617 | 07:34:55.8... | PDCP DL | SCG | 11 | 0 | 2 | | Dropped OOW | 227715 | 227715 | 995 | 4 | 6000 | | | | | | | 227715 | 227715 | |
| 73 | 10:34:56.617 | 07:34:55.8... | PDCP DL | SCG | 11 | 0 | 2 | | Dropped OOW | 227719 | 227719 | 996 | 1 | 1500 | | | | | | | 227719 | 227719 | |
| 74 | 10:34:56.617 | 07:34:55.8... | PDCP DL | SCG | 11 | 0 | 2 | | Dropped OOW | 227841 | 227841 | 1017 | 4 | 6000 | | | | | | | 227841 | 227841 | |
| 75 | 10:34:56.617 | 07:34:55.8... | PDCP DL | SCG | 11 | 0 | 2 | | Dropped OOW | 228471 | 228471 | 144 | 1 | 1500 | | 231791 | 231791 | 234169 | 231791 | 228471 | 228471 | | |
| 76 | 10:34:56.617 | 07:34:55.8... | PDCP DL | SCG | 11 | 0 | 2 | | Dropped OOW | 228485 | 228485 | 1017 | 1 | 1500 | | | | | | | 228485 | 228485 | |
| 77 | 10:34:56.617 | 07:34:55.8... | PDCP DL | SCG | 11 | 1 | 2 | | Dropped OOW | 227863 | 227863 | 0 | 3 | 4500 | | | | | | | 227863 | 227863 | |
| 78 | 10:34:56.617 | 07:34:55.8... | PDCP DL | SCG | 11 | 1 | 2 | | Dropped OOW | 227878 | 227878 | 5 | 5 | 7500 | | | | | | | 227878 | 227878 | |
| 79 | 10:34:56.617 | 07:34:55.8... | PDCP DL | SCG | 11 | 1 | 2 | | Dropped OOW | 227883 | 227883 | 6 | 1 | 1500 | | | | | | | 227883 | 227883 | |
| 80 | 10:34:56.617 | 07:34:55.8... | PDCP DL | SCG | 11 | 1 | 2 | | Dropped OOW | 228472 | 228472 | 144 | 4 | 6000 | | | | | | | 228472 | 228472 | |
| 81 | 10:34:56.617 | 07:34:55.8... | PDCP DL | SCG | 11 | 1 | 2 | | Dropped OOW | 228476 | 228476 | 145 | 1 | 1500 | | | | | | | 228476 | 228476 | |
| 82 | 10:34:56.617 | 07:34:55.8... | PDCP DL | SCG | 11 | 1 | 2 | | Dropped OOW | 228571 | 228571 | 173 | 8 | 12000 | | | | | | | 228571 | 228571 | |
| 83 | 10:34:56.617 | 07:34:55.8... | PDCP DL | SCG | 11 | 1 | 2 | | Dropped OOW | 227846 | 227846 | 1017 | 1 | 1500 | | | | | | | 227846 | 227846 | |
| 84 | 10:34:56.617 | 07:34:55.8... | PDCP DL | SCG | 11 | 1 | 2 | | Dropped OOW | 227847 | 227847 | 1018 | 1 | 1500 | | | | | | | 227847 | 227847 | |
| 85 | 10:34:56.617 | 07:34:55.8... | PDCP DL | SCG | 11 | 1 | 2 | | Dropped OOW | 227853 | 227853 | 1021 | 1 | 1500 | | | | | | | 227853 | 227853 | |

Why Dropped OOW Happens in BOTH MCG and SCG?

This is the most important observation --> PDCP Is Common for MCG and SCG.

In EN-DC:

- PDCP is located in the gNB
- PDCP splits traffic across MCG and SCG
- Reordering is done after packets return from both legs

So although packets are transmitted via:

- MCG (LTE-PCell)
- SCG (NR-PSCell)

→ They share the same PDCP sequence space and reordering window

Therefore:

If reordering fails → both legs can show Dropped OOW

Latency Asymmetry Between MCG and SCG

If MCG and SCG have:

- Different RTTs
- Different HARQ / scheduling delays
- Different BLER / retransmission behavior

Then PDCP packets may arrive:

- Too late from one leg
- Too early from the other

This causes:

- PDCP SN gaps
- Reordering timer expiry
- OOW discards on both MCG and SCG flows

Transport-Layer Interaction (TCP)

When:

- Server A shows high RTT, retransmissions, and slow ramp-up
- TCP retransmissions cause PDCP SN bursts
- Re-injected TCP segments arrive out of order

This further stresses PDCP reordering and accelerates OOW conditions.

Why Dropped OOW Is Severe

Dropped OOW events are not radio retransmissions:

- They happen above RLC/MAC
- HARQ and RLC AM cannot recover them

Impact:

- Direct packet loss at PDCP
- TCP sees loss → retransmissions
- Throughput collapse
- MCS and RB utilization drop