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
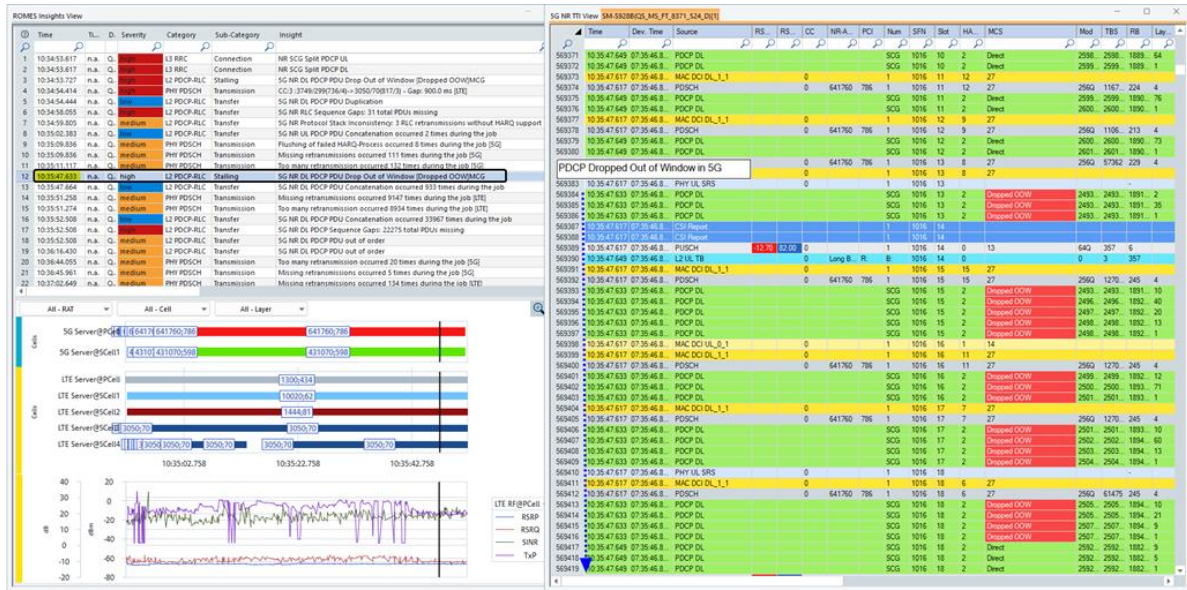
Once a PDCP PDU is OOW:

- 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 thread 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

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