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## **DAI UE Sidelink Intelligence**

Extending DAI UE with SL-NAS Functions

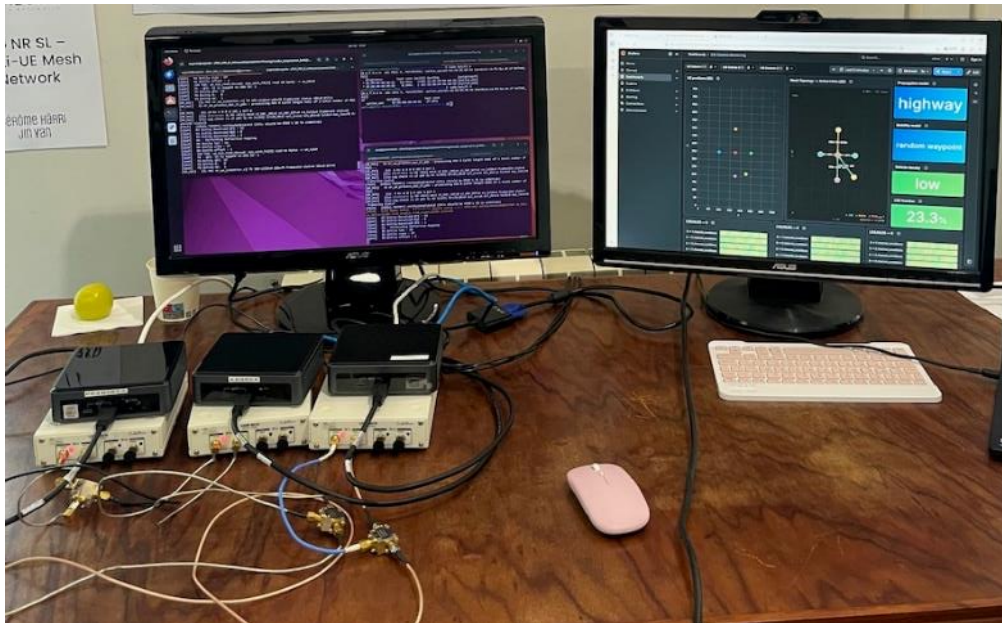
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DAI Workshop 2026

FEUP, Porto, 22-23 June 2026

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# Demo Yesterday - Towards 6G Mesh with OAI NR Sidelink



## ■ 6G MESH Networks:

- 5G NR rel.16 SL (OAI) – dynamic scheduler required...
- Mesh (multi-hop) routing protocol (B.A.T.M.A.N.)
- Joint Relaying & Scheduling approach...required



# 5G NR User Equipment (UE) Sidelink – The Need for UE Intelligence – Need for a UE (SL) NAS

## ■ UE lacks intelligence and control for SL (in particular mode 2)

- Missing Core network and 3GPP MF
- PC5 interface & Relay selection
- 5G NR Sidelink PKI and schedulers

Can Benefit from  
AI Optimization

## ■ UEs have similar O-RAN opportunities as gNBs

- Vendor lock-in
- AI-control mechanisms to UE-RAN
- Intelligent & programmable UE networks
- Automation & Manageability

## ■ UE CU-DU disaggregation ?

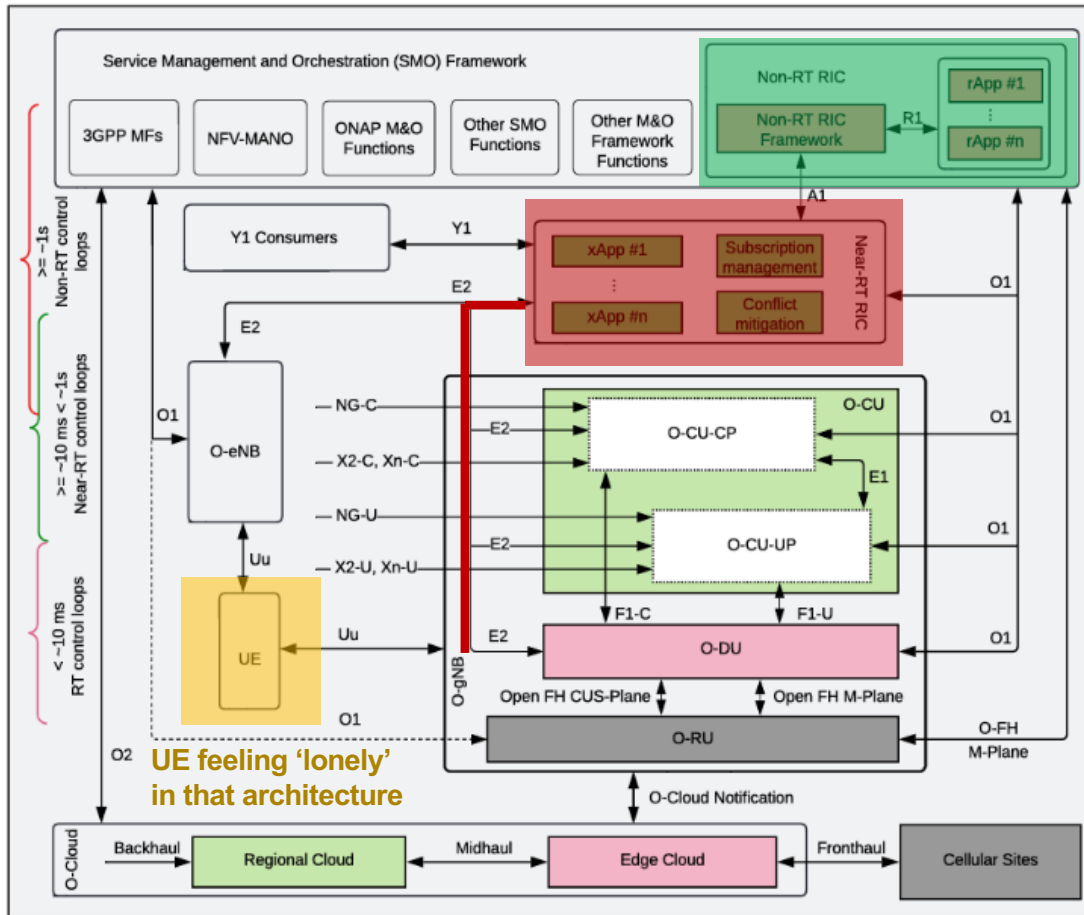
- CU-DU split with CU in AI-edge along with MLops
- Multi-CU-UP for PC5 resource isolation



Nvidia  
spark DGX,  
Thor

5G NR Sidelink (rel. 16)  
5G NR Sidelink ProSe (rel. 17)  
5G NR SL Multi-Relay (rel. 19)

# Open-radio access network (O-RAN) – Architecture & RAN key features



## ■ E2 Interface

- Connects disaggregated gNB (CU-DU)
- Support for
  - RIC Services - Report, Insert, Control, Policy, and Query
  - E2 Services - node config. Etc..

## ■ RAN Intelligent Controllers (RIC)

- software-defined network function (NF) controlling RAN functionalities

## ■ x/r/d-Apps

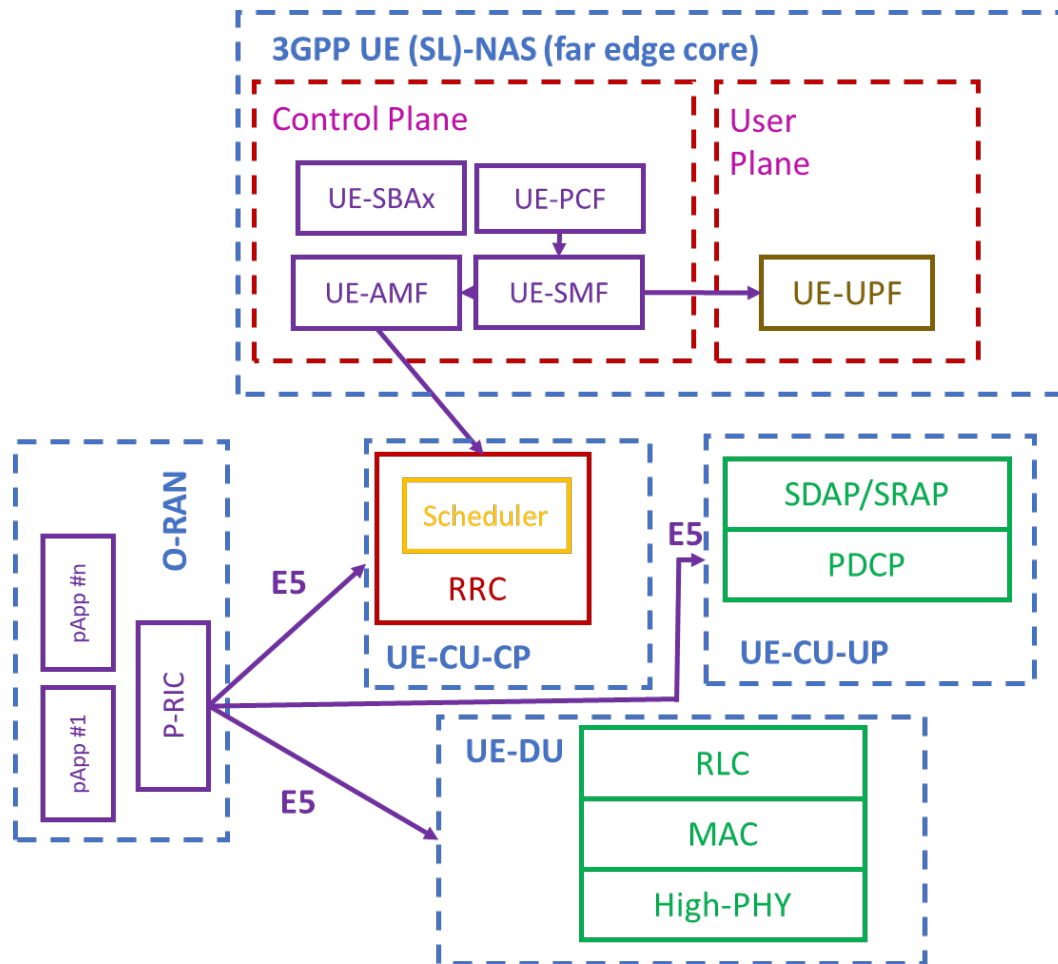
- Modular micro-service-based applications

## ■ O-RAN Service Models

- Key Performance Metric
- Ran Intelligent Control (slicing)
- Cell Configuration and Control

Source: Kurshild Aram et al, "A Comprehensive Tutorial and Survey of O-RAN: Exploring Slicing-aware Architecture, Deployment Options, Use Cases, and Challenges", IEEE Communications Surveys & Tutorials

# SL-NAS & O-RAN for the 5G NR User Equipment (UE) Sidelink – Envisioned Architecture



## ■ E5 node

- UE CU/DU
- Control of RRC and SDAP

## ■ P-RIC

- Resource isolation (slices)
- Dynamic scheduler optimization
- QoS

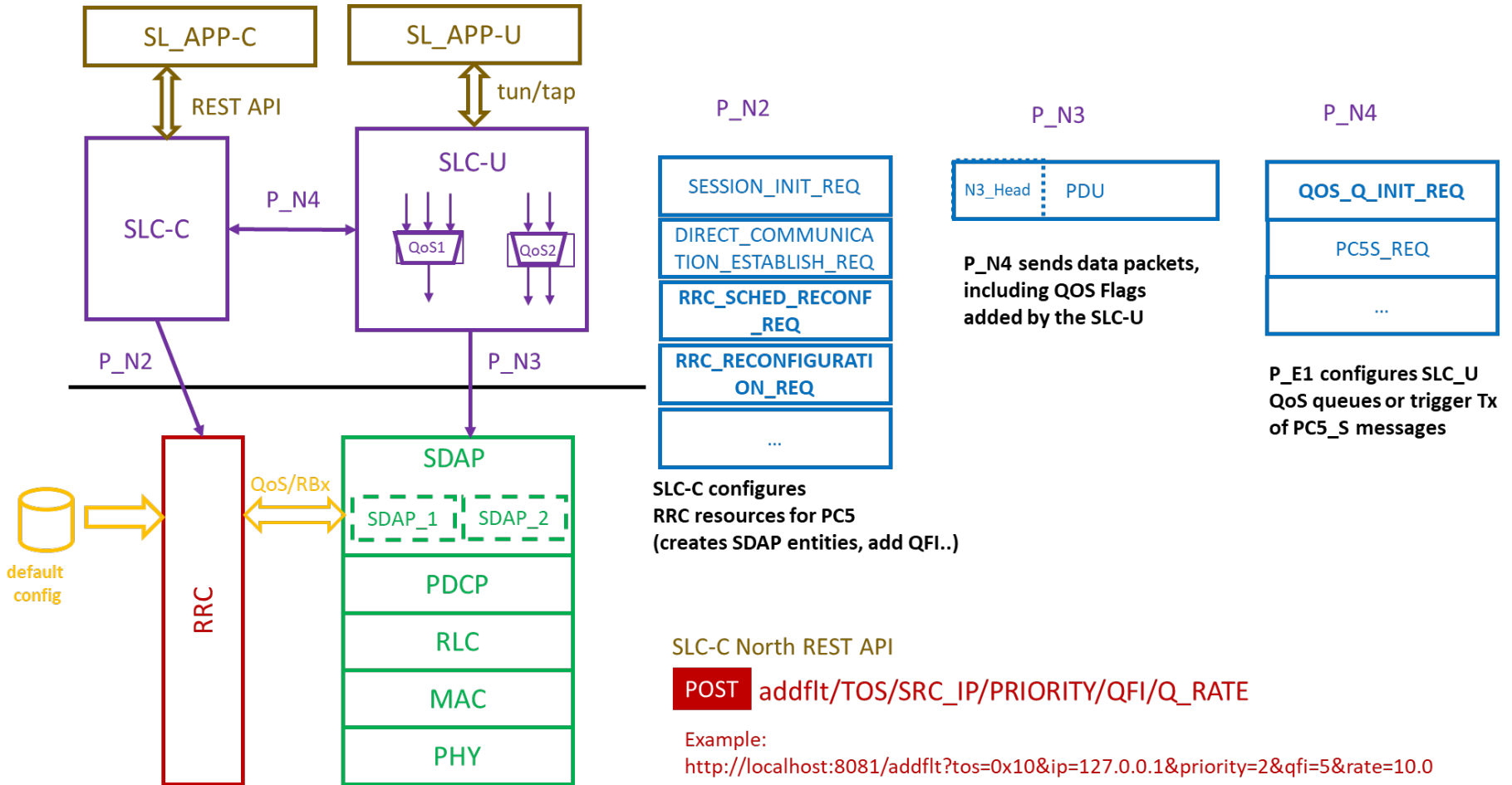
## ■ P-apps

- AI-RAN for PC5
- Extension of ProSe apps

## ■ E5-SM

- KPM
  - ICAS
  - PC5 statistics
- RC
  - AI-driven RAN
  - PC5 Slicing
  - Relay

# OAI SL Prototype with O-RAN-like functions



# OAI SL Prototype with UE (SL) NAS Functions

## ■ SLC QoS Configuration

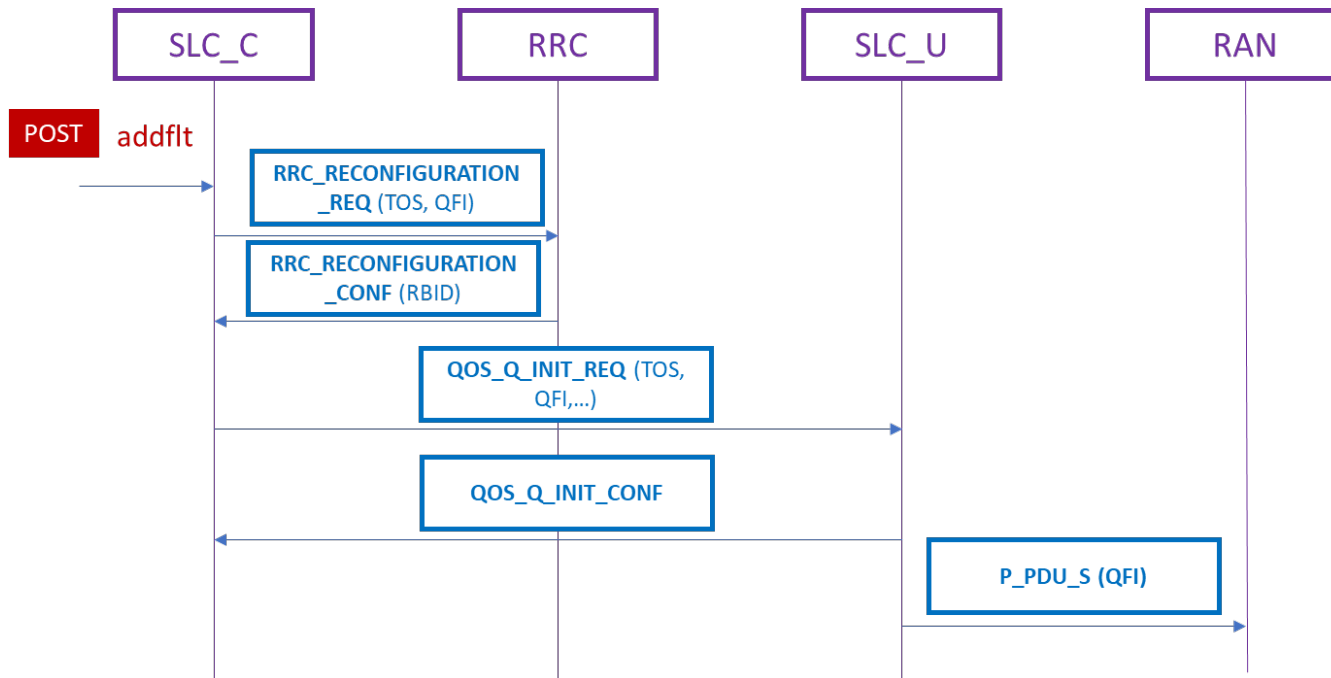
- URLLC - QFI3, TOS=0x10, rate configured at 10 Hz
- Default - QFI1, TOS=0x00, rate configured at 1 Hz

## ■ Traffic Generation:

- 10 Hz (URLL & Default)

PRR (1s): QFI3=40% QFI1=0%  
PRR (5s) : QFI3=41% QFI1=40%  
PRR (10s): QFI3=39% QFI1=30%

MAC allocated resources: 3:1 ratio QFI3:QFI1



# OAI SL Prototype with O-RAN functions

SLC-C

REST API

```
deambulateur@deambulateur:~/rania_5g_work/5g-nr-sidelink-controller$ sudo ip netns exec ue1 curl -sS -X POST 'http://127.0.0.1:8081/addsched?ue=0&slot=0'; echo
sudo ip netns exec ue1 curl -sS -X POST 'http://127.0.0.1:8081/addflt?tos=0x00&ip=10.0.0.2&priority=1&qfi=1&rate=1'; echo
sudo ip netns exec ue1 curl -sS -X POST 'http://127.0.0.1:8081/addflt?tos=0x10&ip=10.0.0.2&priority=3&qfi=3&rate=10'; echo

sudo ip netns exec ue2 curl -sS -X POST 'http://127.0.0.1:8082/addsched?ue=1&slot=1'; echo
sudo ip netns exec ue2 curl -sS -X POST 'http://127.0.0.1:8082/addflt?tos=0x00&ip=10.0.0.1&priority=1&qfi=1&rate=1'; echo
sudo ip netns exec ue2 curl -sS -X POST 'http://127.0.0.1:8082/addflt?tos=0x10&ip=10.0.0.1&priority=3&qfi=3&rate=10'; echo
Scheduler mapping added
Mapping added successfully
Mapping added successfully
Scheduler mapping added
Mapping added successfully
Mapping added successfully
```

SLC-C

P\_N2

```
Endpoints:
POST /addflt?tos=<hex>&ip=<ip>&priority=<int>&qfi=<int>&rate=<float>
POST /removeflt?tos=<hex>&ip=<ip>&priority=<int>
POST /addsched?ue=<0-7>&slot=<0-7>
POST /relsched?ue=<0-7>&slot=<0-7>
[SLC_C] Assigning UE1 to slot 1 (sfid=0x11)
[SLC_C] -----
[SLC_C] Received NR_MACReconfigurationConfirm
[SLC_C] MAC Configuration completed!
[SLC_C] -----
[SLC_C] Send RRCReconfigurationRequest
[SLC_C] -----
[SLC_C] Received RRCReconfigurationAccept
[SLC_C] -----
[SLC_C] Send RRCReconfigurationSetup
[SLC_C] -----
[SLC_C] Received RRCReconfigurationConfirm
[SLC_C] RRC Configuration completed!
```

# OAI SL Prototype with O-RAN functions

SLC-U

QoS Leaky Bucket

```
[SLC_U] Match → QFI=1 PDUID=0 priority=1 rate=1.0
[SLC_U][DEBUG] ver=4 ihl=5 proto=1 src=10.0.0.1 dst=10.0.0.1 raw_tos=0x10 first_bytes=45 10 00
54\n[SLC_U] Packet → 10.0.0.2 TOS=0x10
[SLC_U] Match → QFI=3 PDUID=0 priority=3 rate=10.0
[SLC_U] Leaked 84 bytes (priority=1 qfi via TOS)
[SLC_U] Leaked 84 bytes (priority=3 qfi via TOS)
[SLC_U][DEBUG] ver=4 ihl=5 proto=1 src=10.0.0.1 dst=10.0.0.1 raw_tos=0x00 first_bytes=45 00 00
54\n[SLC_U] Packet → 10.0.0.2 TOS=0x00
[SLC_U] Match → QFI=1 PDUID=0 priority=1 rate=1.0
[SLC_U][DEBUG] ver=4 ihl=5 proto=1 src=10.0.0.1 dst=10.0.0.1 raw_tos=0x10 first_bytes=45 10 00
54\n[SLC_U] Packet → 10.0.0.2 TOS=0x10
[SLC_U] Match → QFI=3 PDUID=0 priority=3 rate=10.0
[SLC_U] Leaked 84 bytes (priority=1 qfi via TOS)
[SLC_U] Leaked 84 bytes (priority=3 qfi via TOS)
```

QoS QFI-1 & QFI-3

OAI SL IFs

```
4: oaitun_ue1: <POINTOPOINT,MULTICAST,NOARP,UP,LOWER_UP> mtu 1500 qd
fault qlen 500
  link/none
  inet 10.0.0.1/24 brd 10.0.0.255 scope global oaitun_ue1
    valid_lft forever preferred_lft forever
  inet6 fe80::b43b:28fd:598c:1420/64 scope link stable-privacy
    valid_lft forever preferred_lft forever
5: oaitun_ue2: <POINTOPOINT,MULTICAST,NOARP,UP,LOWER_UP> mtu 1500 qd
fault qlen 500
  link/none
  inet 10.0.0.2/24 brd 10.0.0.255 scope global oaitun_ue2
    valid_lft forever preferred_lft forever
  inet6 fe80::49fb:daff:43b2:71dc/64 scope link stable-privacy
    valid_lft forever preferred_lft forever
```

```
===== QFI3 URLLC =====
--- 10.0.0.2 ping statistics ---
10 packets transmitted, 6 received, 40% packet loss, time 930ms
rtt min/avg/max/mdev = 1537.546/1884.598/2160.022/204.795 ms, pipe 9
===== QFI1 NORMAL =====
--- 10.0.0.2 ping statistics ---
10 packets transmitted, 1 received, 90% packet loss, time 937ms
rtt min/avg/max/mdev = 33.851/33.851/33.851/0.000 ms
```

```
[NR_PHY] =====
[NR_PHY] [UE0] 128:17 PSBCH Stats: TX 25, RX ok 0, RX not ok 0
[NR_PHY] [UE0] 128:17 PSSCH Stats: TX 0, RX ok 0
[NR_PHY] [UE0] 128:17 PSSCH/SCI2 Stats: TX 0, RX ok 0, RX not ok 0
[NR_PHY] [UE0] 128:17 PSSCH Stats: TX 0, RX ok 0, RX not ok (0/0/0/0)
[NR_PHY] [UE0] 128:17 PSFCH Stats: TX 0
[NR_PHY] =====
[NR_PHY] [UE0] 128:18 PSBCH Stats: TX 25, RX ok 0, RX not ok 0
[NR_PHY] [UE0] 128:18 PSSCH Stats: TX 0, RX ok 0
[NR_PHY] [UE0] 128:18 PSSCH/SCI2 Stats: TX 0, RX ok 0, RX not ok 0
[NR_PHY] [UE0] 128:18 PSSCH Stats: TX 0, RX ok 0, RX not ok (0/0/0/0)
[NR_PHY] [UE0] 128:18 PSFCH Stats: TX 0
[NR_PHY] =====
```

UE1

# Wrapping up...

## ■ So far...

- UE SL lacks programmability & intelligence
- 5G NR SL/MANET would require intelligent & programmable interfaces
- First UE (SL)-NAS (O-RAN-like) UE architecture supporting UE programmability & intelligence

## ■ Next...

- Define O-RAN SM, E5, P-RIC architecture, enable PC5 slicing SMs
- Implement on OAI UE SL and test using our new SL\_RFSIM



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