AFFORDABLE 5G

Status of OAI O-DU integration with commercial RU

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OPEN AIR INTERFACE

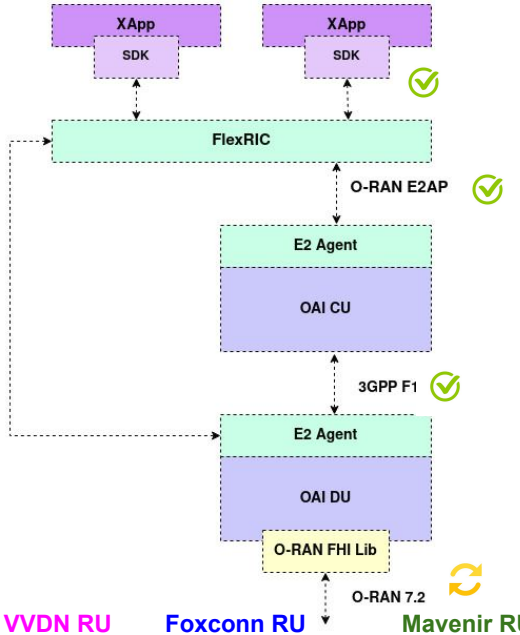
Objective

Leverage the O-RAN FHI 7.2 specification to demonstrate multi-vendor disaggregated RAN interoperability

- EURECOM OAI-DU with the O-RAN 7.2 FHI interface
- RunEL REL-RU with the O-RAN 7.2 FHI interface

Validated milestones
E2E architecture and network components

- FlexRIC as an open source O-RAN nRT-RIC with XApp and SDK
- 3GPP F1
  - OAI-CU - OAI-DU
  - ACC-CU -OAI-DU
- ORAN 7.2
  - OAI-DU and O-RAN RU SIM
  - OAI-DU and FOXCONN RU

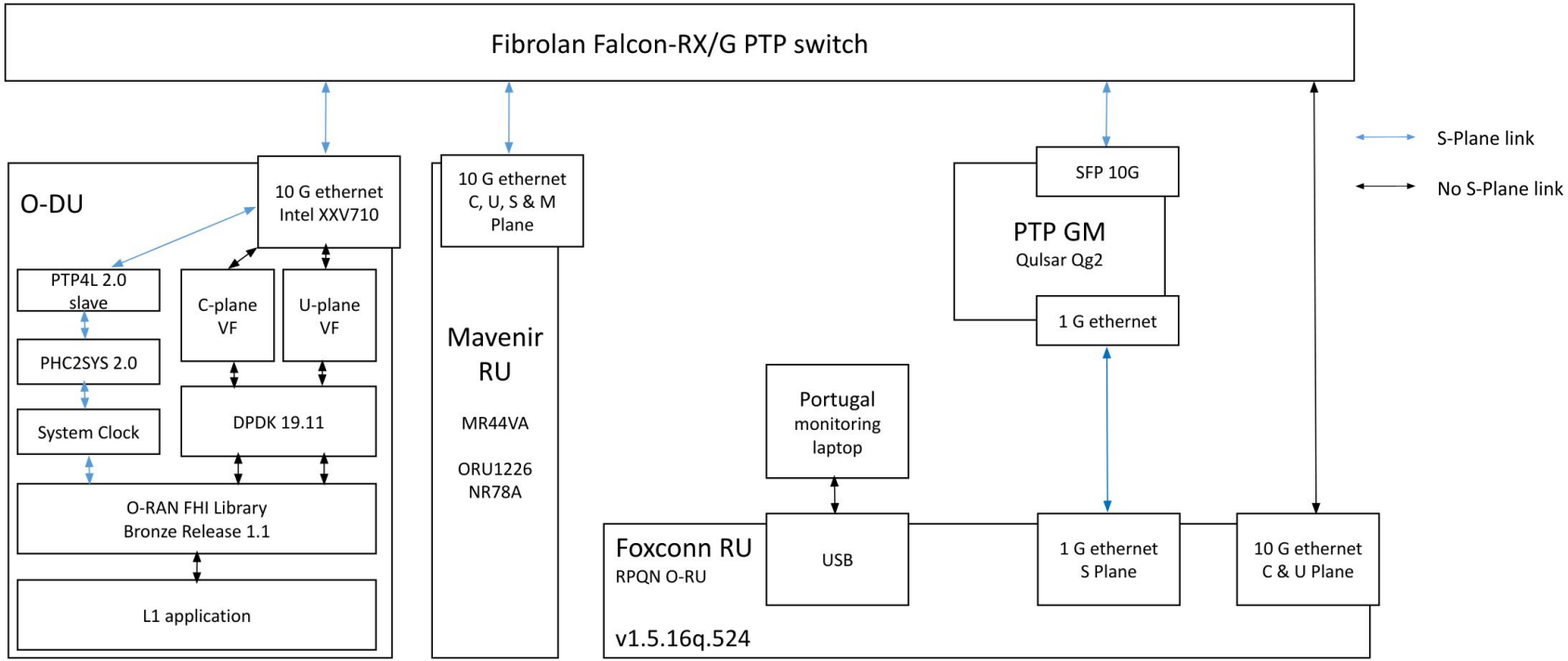


VVDN RU

Foxconn RU

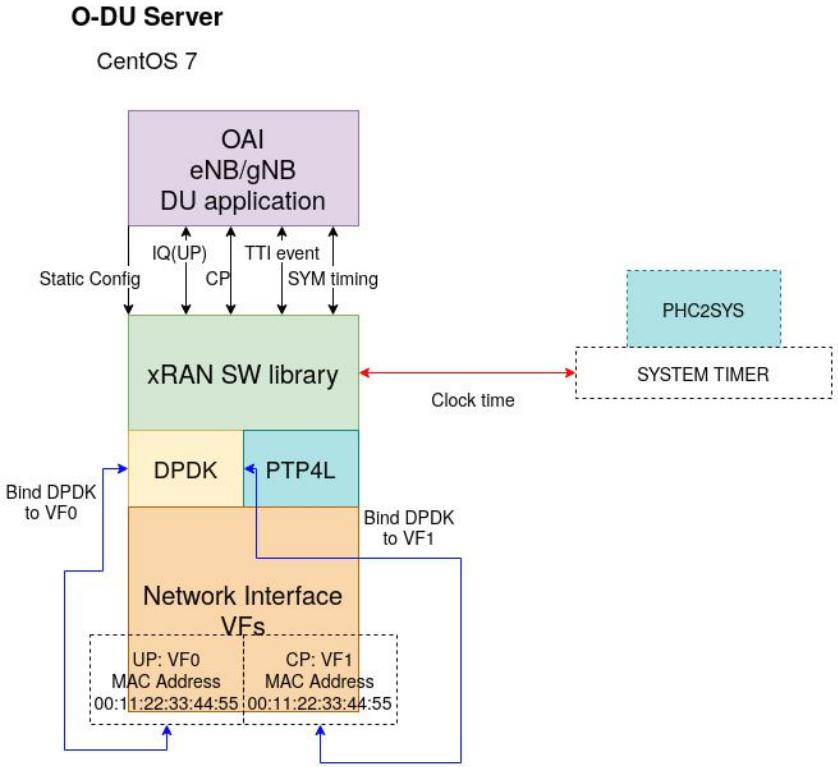
Mavenir RU

Part of Eurecom O-RAN 7.2 Testbed



O-RAN FHI 7.2 Integration in OAI

OAI O-DU software architecture



- OAI eNB/gNB application: PHY layer implementing O-RAN 7.2 FH using xRAN library functions
- O-RAN xRAN library: built on top of DPDK to provide O-RAN 7.2 FH specification functionalities
- DPDK: Interface to the ETH port
  - Binded on two different VFs for U-Plane and C-Plane
- Linux PTP
  - PTP4L, PHC2SYS
  - S-Plane

Validated milestones - O-RAN 7.2

- Integration of the O-RAN FHI X-RAN library into OAI DU
- OAI-DU FHI 7.2 split development CP and UP
- Validation of the CP/UP development using O-RAN O-RU sample app
- Connection to the Foxconn RU is successful
  - M-plane : manually configured, later it will be integrate with NETCONF
  - S-plane: done
  - U-plane : done
  - C-plane : to be validated
- S-Plane validation both with
  - Local master - O-DU machine assuming grand master role
  - Grand master in the network

Sample App O-DU - Foxconn RU

```
Start XRAN traffic
O-DU: thread_run start time: 05/18/22 07:35:16.000000010 UTC [1000]
Start C-plane DL 0 us after TTI  [trigger on sym 1]
Start C-plane UL 440 us after TTI  [trigger on sym 7]
Start U-plane DL 400 us before OTA [offset  in sym -5]
Start U-plane UL 360 us OTA        [offset  in sym 6]
C-plane to U-plane delay 400 us after TTI
Start Sym timer 142857 ns
interval_us 1000
+---------------------------------------+
| Press 1 to start 5G NR XRAN traffic   |
| Press 2 reserved for future use       |
| Press 3 to quit                       |
+---------------------------------------+
[o-du][rx  114642 pps  114642 kbps 1336832][tx  131104 pps  131104 kbps 1346442] [on_time 114642 early 0 late 0 corrupt 0 pkt_dupl 4 Total 114642] IO Util: 56.29 %
[o-du][rx  170654 pps   56012 kbps 1336832][tx  195132 pps   64028 kbps 1346440] [on_time 170654 early 0 late 0 corrupt 0 pkt_dupl 4 Total 170654] IO Util: 57.06 %
[o-du][rx  226664 pps   56010 kbps 1336832][tx  259164 pps   64032 kbps 1346440] [on_time 226664 early 0 late 0 corrupt 0 pkt_dupl 4 Total 226664] IO Util: 57.05 %
[o-du][rx  282674 pps   56010 kbps 1336832][tx  323196 pps   64032 kbps 1346440] [on_time 282674 early 0 late 0 corrupt 0 pkt_dupl 4 Total 282674] IO Util: 57.01 %
[o-du][rx  338684 pps   56010 kbps 1336832][tx  387228 pps   64032 kbps 1346442] [on_time 338684 early 0 late 0 corrupt 0 pkt_dupl 4 Total 338684] IO Util: 57.04 %
[o-du][rx  394684 pps   56000 kbps 1336832][tx  451256 pps   64028 kbps 1346440] [on_time 394684 early 0 late 0 corrupt 0 pkt_dupl 4 Total 394684] IO Util: 57.01 %
[o-du][rx  450684 pps   56000 kbps 1336832][tx  515288 pps   64032 kbps 1346440] [on_time 450684 early 0 late 0 corrupt 0 pkt_dupl 4 Total 450684] IO Util: 57.06 %
[o-du][rx  506684 pps   56000 kbps 1336832][tx  579316 pps   64028 kbps 1346440] [on_time 506684 early 0 late 0 corrupt 0 pkt_dupl 4 Total 506684] IO Util: 57.05 %
[o-du][rx  562684 pps   56000 kbps 1336832][tx  643344 pps   64028 kbps 1346442] [on_time 562684 early 0 late 0 corrupt 0 pkt_dupl 4 Total 562684] IO Util: 57.09 %
[o-du][rx  618684 pps   56000 kbps 1336832][tx  707376 pps   64032 kbps 1346440] [on_time 618684 early 0 late 0 corrupt 0 pkt_dupl 4 Total 618684] IO Util: 57.02 %
[o-du][rx  674684 pps   56000 kbps 1336832][tx  771408 pps   64032 kbps 1346440] [on_time 674684 early 0 late 0 corrupt 0 pkt_dupl 4 Total 674684] IO Util: 57.03 %
[o-du][rx  730691 pps   56007 kbps 1336832][tx  835440 pps   64032 kbps 1346440] [on_time 730691 early 0 late 0 corrupt 0 pkt_dupl 4 Total 730691] IO Util: 57.01 %
[o-du][rx  786700 pps   56009 kbps 1336832][tx  899468 pps   64028 kbps 1346442] [on_time 786700 early 0 late 0 corrupt 0 pkt_dupl 4 Total 786700] IO Util: 57.02 %
[o-du][rx  842708 pps   56008 kbps 1336832][tx  963496 pps   64028 kbps 1346440] [on_time 842708 early 0 late 0 corrupt 0 pkt_dupl 4 Total 842708] IO Util: 57.03 %
[o-du][rx  898718 pps   56010 kbps 1336832][tx 1027528 pps   64032 kbps 1346440] [on_time 898718 early 0 late 0 corrupt 0 pkt_dupl 4 Total 898718] IO Util: 57.27 %
[o-du][rx  954728 pps   56010 kbps 1336832][tx 1091556 pps   64028 kbps 1346440] [on_time 954728 early 0 late 0 corrupt 0 pkt_dupl 4 Total 954728] IO Util: 57.13 %
[o-du][rx 1010736 pps   56008 kbps 1336832][tx 1155584 pps   64028 kbps 1346442] [on_time 1010736 early 0 late 0 corrupt 0 pkt_dupl 4 Total 1010736] IO Util: 57.17 %
```

Sample App O-DU, Tx/Rx packets to Foxconn RU

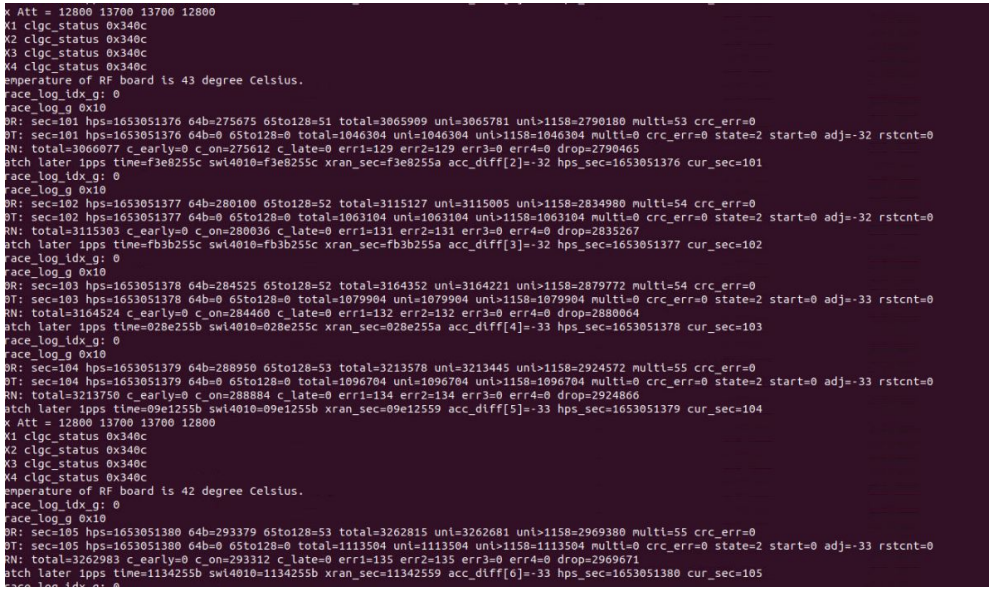
OAI-DU - Foxconn RU

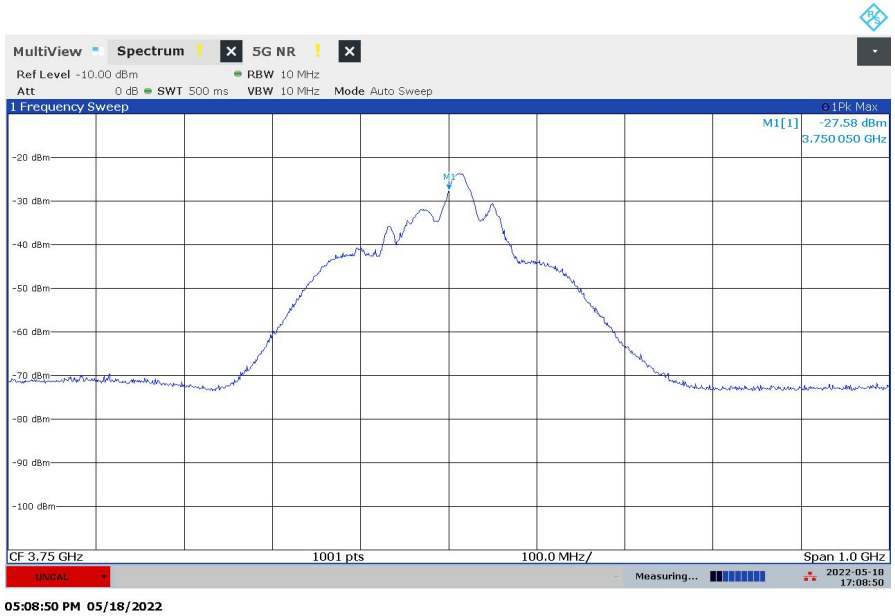
	Time	Source	Destination	Protocol	Length	Info
1	0.000000000	66:44:33:22:11:00	6c:ad:ad:00:04:dc	O-RAN-FH-C	60	C-Plane, Type: 1 (Most channels), Id: 0 (PRB: 0-105)
2	0.000000202	66:44:33:22:11:00	6c:ad:ad:00:04:dc	O-RAN-FH-C	60	C-Plane, Type: 1 (Most channels), Id: 0 (PRB: 0-105)
3	0.000000265	66:44:33:22:11:00	6c:ad:ad:00:04:dc	O-RAN-FH-C	60	C-Plane, Type: 1 (Most channels), Id: 0 (PRB: 0-105)
4	0.000000326	66:44:33:22:11:00	6c:ad:ad:00:04:dc	O-RAN-FH-C	60	C-Plane, Type: 1 (Most channels), Id: 0 (PRB: 0-105)
5	0.000324230	66:44:33:22:11:00	6c:ad:ad:00:04:dc	O-RAN-FH-U	5122	U-Plane, Id: 0 (PRB: 0-105)
6	0.000324305	66:44:33:22:11:00	6c:ad:ad:00:04:dc	O-RAN-FH-U	5122	U-Plane, Id: 0 (PRB: 0-105)
7	0.000324380	66:44:33:22:11:00	6c:ad:ad:00:04:dc	O-RAN-FH-U	5122	U-Plane, Id: 0 (PRB: 0-105)
8	0.000350927	66:44:33:22:11:00	6c:ad:ad:00:04:dc	O-RAN-FH-U	5122	U-Plane, Id: 0 (PRB: 0-105)
9	0.000386758	66:44:33:22:11:00	6c:ad:ad:00:04:dc	O-RAN-FH-U	5122	U-Plane, Id: 0 (PRB: 0-105)
10	0.000386845	66:44:33:22:11:00	6c:ad:ad:00:04:dc	O-RAN-FH-U	5122	U-Plane, Id: 0 (PRB: 0-105)
11	0.000386918	66:44:33:22:11:00	6c:ad:ad:00:04:dc	O-RAN-FH-U	5122	U-Plane, Id: 0 (PRB: 0-105)
12	0.000386988	66:44:33:22:11:00	6c:ad:ad:00:04:dc	O-RAN-FH-U	5122	U-Plane, Id: 0 (PRB: 0-105)
13	0.000441717	66:44:33:22:11:00	6c:ad:ad:00:04:dc	O-RAN-FH-U	5122	U-Plane, Id: 0 (PRB: 0-105)
14	0.000441784	66:44:33:22:11:00	6c:ad:ad:00:04:dc	O-RAN-FH-U	5122	U-Plane, Id: 0 (PRB: 0-105)
15	0.000441847	66:44:33:22:11:00	6c:ad:ad:00:04:dc	O-RAN-FH-U	5122	U-Plane, Id: 0 (PRB: 0-105)

	Time	Source	Destination	Protocol	Length	Info
1	0.000000000	66:44:33:22:11:00	6c:ad:ad:00:04:dc	O-RAN-FH-U	5122	U-Plane, Id: 0 (PRB: 0-105)
2	0.000000063	66:44:33:22:11:00	6c:ad:ad:00:04:dc	O-RAN-FH-U	5122	U-Plane, Id: 0 (PRB: 0-105)
3	0.000000127	66:44:33:22:11:00	6c:ad:ad:00:04:dc	O-RAN-FH-U	5122	U-Plane, Id: 0 (PRB: 0-105)
4	0.000000190	66:44:33:22:11:00	6c:ad:ad:00:04:dc	O-RAN-FH-U	5122	U-Plane, Id: 0 (PRB: 0-105)
5	0.000000253	66:44:33:22:11:00	6c:ad:ad:00:04:dc	O-RAN-FH-U	5122	U-Plane, Id: 0 (PRB: 0-105)
6	0.000000314	66:44:33:22:11:00	6c:ad:ad:00:04:dc	O-RAN-FH-U	5122	U-Plane, Id: 0 (PRB: 0-105)
7	0.000000379	66:44:33:22:11:00	6c:ad:ad:00:04:dc	O-RAN-FH-U	5122	U-Plane, Id: 0 (PRB: 0-105)
8	0.000000441	66:44:33:22:11:00	6c:ad:ad:00:04:dc	O-RAN-FH-U	5122	U-Plane, Id: 0 (PRB: 0-105)
9	0.000021731	6c:ad:ad:00:04:dc	66:44:33:22:11:00	O-RAN-FH-U	5122	U-Plane, Id: 0 (PRB: 0-105)
10	0.000021791	6c:ad:ad:00:04:dc	66:44:33:22:11:00	O-RAN-FH-U	5122	U-Plane, Id: 0 (PRB: 0-105)
11	0.000021855	6c:ad:ad:00:04:dc	66:44:33:22:11:00	O-RAN-FH-U	5122	U-Plane, Id: 0 (PRB: 0-105)
12	0.000021918	6c:ad:ad:00:04:dc	66:44:33:22:11:00	O-RAN-FH-U	5122	U-Plane, Id: 0 (PRB: 0-105)
13	0.000021981	6c:ad:ad:00:04:dc	66:44:33:22:11:00	O-RAN-FH-U	5122	U-Plane, Id: 0 (PRB: 0-105)
14	0.000022044	6c:ad:ad:00:04:dc	66:44:33:22:11:00	O-RAN-FH-U	5122	U-Plane, Id: 0 (PRB: 0-105)
15	0.000022108	66:44:33:22:11:00	6c:ad:ad:00:04:dc	O-RAN-FH-U	5122	U-Plane, Id: 0 (PRB: 0-105)
16	0.000022170	66:44:33:22:11:00	6c:ad:ad:00:04:dc	O-RAN-FH-U	5122	U-Plane, Id: 0 (PRB: 0-105)

wireshark capture
- CP
- UP in UL/DL

Foxconn logs and spectrum analyzer output





Foxconn O-RU logs
(Status 2: means both sending and receiving)

Signal generated from Foxconn RU
(to be further verified)

Integration with RunEL RU

- Provide Sample App for O-DU simulator
- Support RunEL team for their testbed configuration
- Objective: validation of the RunEL O-RU with the CP/UP O-RAN FHI library generated packets

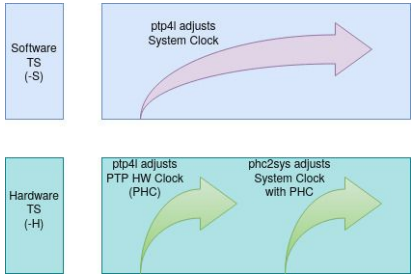
O-RAN FHI 7.2 S-Plane compatibility

O-RAN FHI S-Plane

The O-RAN FHI library checks the machine synchronization via the function:

- xran_is_synchronized() in /lib/src/xran_sync_api.c
- It checks if ptp4l and phc2sys are running in the system by making PMC tool requests for the current port state and comparing it with the expected value
- checking only “SLAVE” as the only expected value only a non-master scenario is supported currently
- O-RAN FHI lib requires ptp4l in HW mode + phc2sys

- ptp4l HW timestamping option
  - ptp4l to adjust the HW clock (PHC)
  - phc2sys adjusts the System Clock with PHC



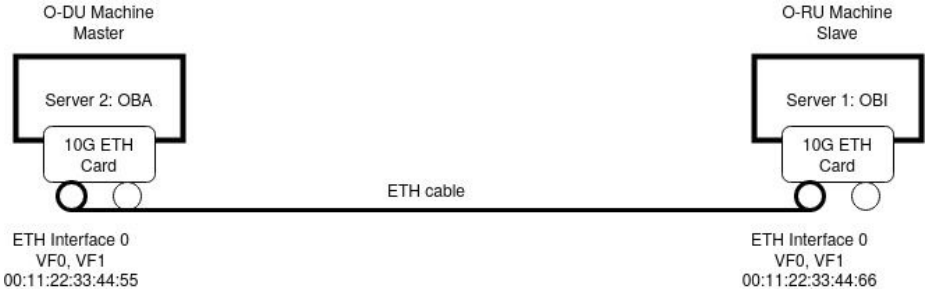
- ptp4l message compatible with IEEE 802.3 (option -2)
  - option -4 → PTP message over L2, UDP IPv4
  - option -6 → PTP message over L2, UDP IPv6

```
Network Transport

-2          IEEE 802.3
-4          UDP IPV4 (default)
-6          UDP IPV6

Time Stamping

-H          HARDWARE (default)
-S          SOFTWARE
-L          LEGACY HW
```

- phc2sys
  - option -w → wait for ptp4l
  - option -R 8 → slave clock update rate (8 HZ)

O-RAN FHI S-Plane - Local master

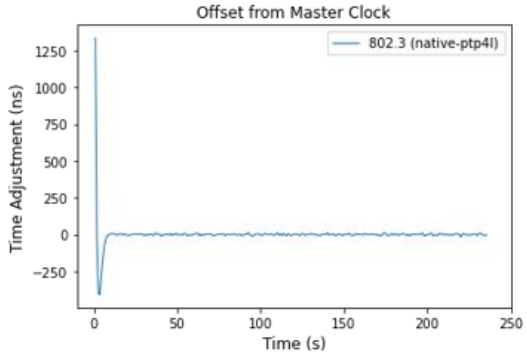
Configuration and summary of the results



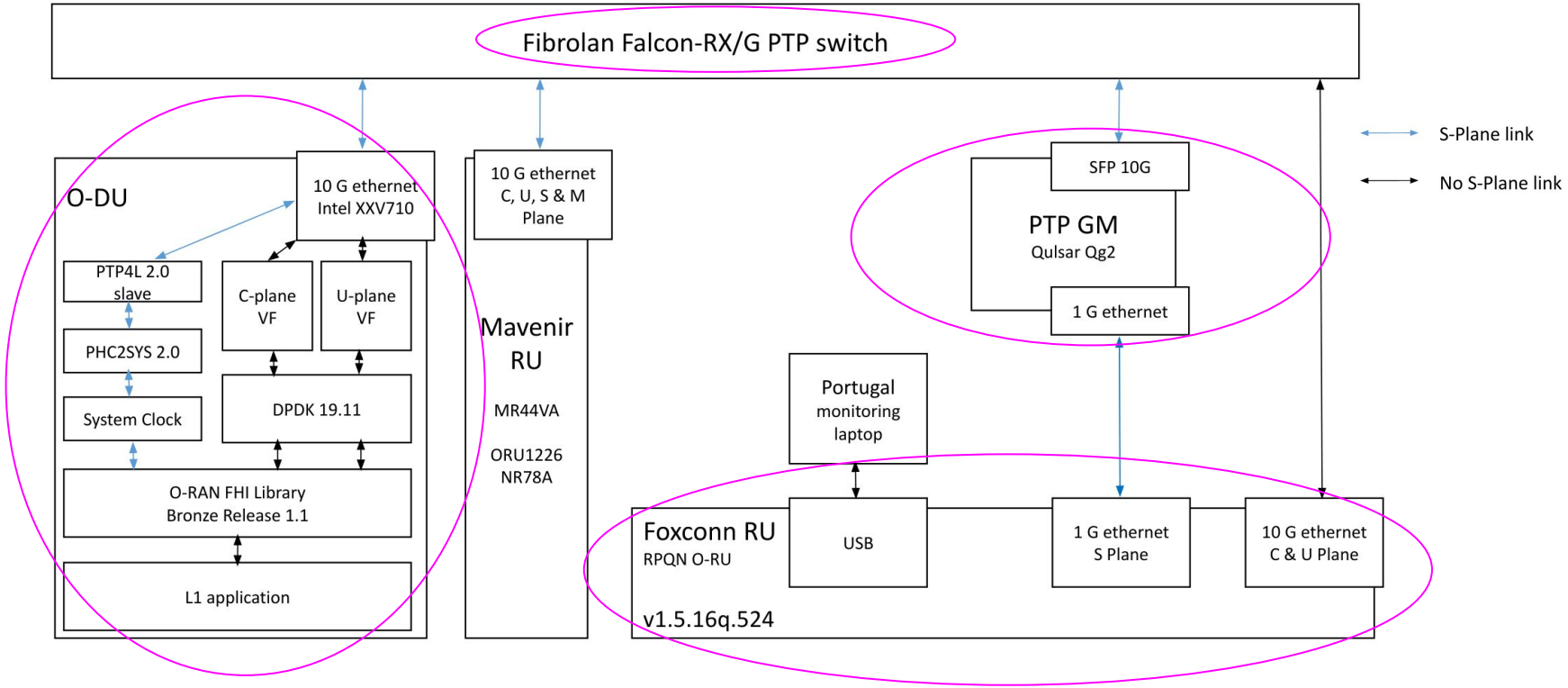

```
obi@localhost:~/linuxptp
obi@localhost:~/linuxptp$ sudo ptp4l -i enp101s0f0 -H -2 -s -m
[sudo] password for obi:
ptp4l[152584.240]: selected /dev/ptp2 as PTP clock
ptp4l[152584.282]: port 1: INITIALIZING to LISTENING on INIT_COMPLETE
ptp4l[152584.282]: port 0: INITIALIZING to LISTENING on INIT_COMPLETE
ptp4l[152585.629]: port 1: new foreign master 649d99.fffe.b17ba4-1
ptp4l[152589.296]: selected best master clock 649d99.fffe.b17ba4
ptp4l[152589.296]: port 1: LISTENING to UNCALIBRATED on RS_SLAVE
ptp4l[152591.129]: master offset       1330 s0 freq    +823 path delay      1071
ptp4l[152592.045]: master offset       1326 s2 freq    +819 path delay      1071
ptp4l[152592.045]: port 1: UNCALIBRATED to SLAVE on MASTER_CLOCK_SELECTED
ptp4l[152592.962]: master offset       1334 s2 freq   +2153 path delay      1065
ptp4l[152593.879]: master offset         -5 s2 freq   +1214 path delay      1065
ptp4l[152594.795]: master offset       -403 s2 freq    +815 path delay      1067
ptp4l[152595.712]: master offset       -408 s2 freq    +689 path delay      1067
ptp4l[152596.629]: master offset       -274 s2 freq    +700 path delay      1064
ptp4l[152597.546]: master offset       -158 s2 freq    +734 path delay      1063
ptp4l[152598.462]: master offset        -70 s2 freq    +775 path delay      1063
ptp4l[152599.379]: master offset        -28 s2 freq    +796 path delay      1063
ptp4l[152600.296]: master offset         -4 s2 freq    +811 path delay      1061
ptp4l[152601.212]: master offset         -4 s2 freq    +810 path delay      1061
```

1 2 3 4

1. Offset from Master Clock
2. s0: unclock
   s1: clock step
   s2: locked
3. PHC Frequency Adjustment (pbb)
4. Path Delay values between Master and Slave Clocks



Test Network Topology - Grand Master



O-RAN FHI S-Plane - Grand master

Configuration and summary of the results

Check if the machine is synchronized with the Grand Master using O-DU sample app which calls xran_is_synchronized()

1	0.000000	FsCom_b1:95:ff	IEEEI&MS_00:00:00	PTPv2	58 Delay_Req Message
2	0.000017	FibroLAN_07:dc:b5	IEEEI&MS_00:00:00	PTPv2	70 Delay_Resp Message
3	0.023506	FibroLAN_07:dc:b5	IEEEI&MS_00:00:00	PTPv2	60 Sync Message
4	0.034661	FsCom_b1:95:ff	IEEEI&MS_00:00:00	PTPv2	58 Delay_Req Message
5	0.034676	FibroLAN_07:dc:b5	IEEEI&MS_00:00:00	PTPv2	70 Delay_Resp Message
6	0.089665	FibroLAN_07:dc:b5	IEEEI&MS_00:00:00	PTPv2	78 Announce Message
7	0.097971	FibroLAN_07:dc:b5	IEEEI&MS_00:00:00	PTPv2	60 Sync Message
8	0.101929	FsCom_b1:95:ff	IEEEI&MS_00:00:00	PTPv2	58 Delay_Req Message
9	0.101943	FibroLAN_07:dc:b5	IEEEI&MS_00:00:00	PTPv2	70 Delay_Resp Message
10	0.171376	FibroLAN_07:dc:b5	IEEEI&MS_00:00:00	PTPv2	60 Sync Message
11	0.215379	FsCom_b1:95:ff	IEEEI&MS_00:00:00	PTPv2	58 Delay_Req Message

← *ptpv2 captured packets in O-DU machine*

```
sudo ./ptp4l -i enp101s0f1 -m -H -2 -s
sudo ./phc2sys -w -m -s enp101s0f1 -r
```

← *Commands to run for the PTP synchronization*

```
================================================================================================================
SAMPLE-APP VERSION
================================================================================================================
Version: oran_bronze_release_v1.1
build-date: Nov 26 2021
build-time: 16:31:09
arg_params_cfg_file (./usecase/mu0_20mhz/config_file_o_du_comp.dat)
Machine is synchronized using PTP!
instance_id 0
mu_number: 0
```

← *Sample app O-DU showing the PTP machine synchronization to the Grand Master*

O-RAN FHI S-Plane - Grand master

OAI O-DU result summary

```
610 [PHY]   DJP - delete code above this /home/obi/OAI/old_fhi/openairinterface5g/executables/nr-ru.c:1860
611 [PHY]   Copying frame parms from gNB in RC to gNB 0 in ru 0 and frame_parms in ru
612 [LIBCONFIG] device.recplay: 7/7 parameters successfully set, (7 to default value)
613 [LIBCONFIG] device: 1/1 parameters successfully set, (1 to default value)
614 [LIBCONFIG] loader: 2/2 parameters successfully set, (2 to default value)
615 [LIBCONFIG] loader.oai_transpro: 2/2 parameters successfully set, (1 to default value)
616 [LOADER] library liboai_transpro.so successfully loaded
617 wrapper.hpp: m_xranInit.io_cfg.dpdk_dev[0] =0000:65:0a.0, m_xranInit.io_cfg.dpdk_dev[1]=0000:65:0a.1
618 ORAN: transport_init
619 Machine is synchronized using PTP!
620 O-DU MAC address: 66:44:33:22:11:00
621 O-RU MAC address: 6C:FFFFFFAD:FFFFFFAD:00:04:FFFFFFDC
622 eAxCID - 12:8:4:0 (f000, 0f00, 00f0, 000f)
623 Total BF Weights : 64
624  xran_init: MTU 9000
```

Next Steps

Next steps

- Integration Validation of the C-U Planes with commercial RU
- PRACH Development
- Timing tuning between OAI-DU and O-RU
- Connection with COTS UEs
- Integration with RunEL RU
- FlexRIC additional features, such as slicing, are under development and integration

Partners

GET IN TOUCH

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THIS PROJECT IS PART OF THE 5G PUBLIC AND PRIVATE PARTNERSHIP

5G PPP WWW.5G-PPP.EU

Affordable5G project is funded by the EU's Horizon2020 programme under Grant Agreement number 957317.

AFFORDABLE 5G

THANKS FOR YOUR ATTENTION

Complementary and Backup slides

xRAN SW library project

Integration top level approach

1) Standalone code to understand the xRAN library usage “DU simulator”. Steps:
   a) Read the IQ samples from a matlab generated file
   b) Fill the xRAN TX buffer once
   c) Start the xRAN library threads and callbacks for TX/RX packets
   d) Read the xRAN library buffer on regular basis
   e) Compute the statistics
2) Incorporate the xRAN library in OAI project
   a) Include the useful xRAN files and make the OAI project compile using the ORAN FHI
   b) Reuse the steps of the standalone code to verify the correct library integration but inside OAI project

xRAN SW library project

Integration top level approach

3) Connect the real OAI generated data for TX to the xRAN TX buffers
   a) Do not read the IQs from the Matlab file anymore
   b) Subframe timing
4) Connect the RX xRAN buffer to the OAI RX buffers
   a) Subframe timing
5) Test this connection with the RU-Simulator
6) Make OAI configuration file for the ORAN FHI
   a) Get rid of the json configuration file that is currently used by the xRAN library wrapper (xranlib_wrapper.hpp)
   b) the xRAN configuration parameters should directly come from the OAI configuration file
7) Implement the O-RAN 7.2 Messages For the RU control
8) Connect to the commercial RUs and test the Radio Interface

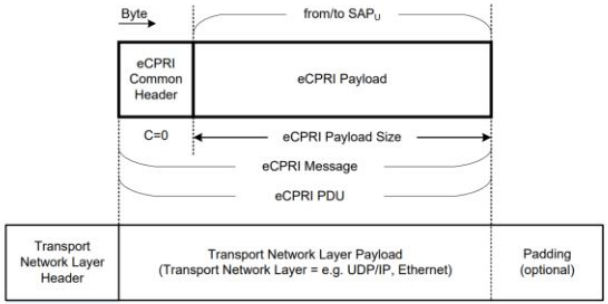
RunEL RU - OAI DU integration challenges

1. RunEL RU is O-ran compliant but the O-RAN messages are encapsulated at L3 (UDP)
   a. L3 still valid for the specification
   b. xRAN libraries do not (yet) implement it. It is in the future program
   c. xRAN library uses the L2 encapsulation
2. OAI uses the xRAN libraries
3. Is RunEL RU capable to connect UE like Quectel in the setup independently from OAI DU?

eCPRI and IEEE 802.3 for the encapsulation

- eCPRI packets could be encapsulated UDP/IP or Ethernet
  - Ethernet IEEE 802.3
- O-RAN packets are encapsulated eCPRI

https://www.techplayon.com/what-is-ecpri-how-it-contributes-to-5g-and-open-ran/



Linux PTP for S-Plane

PTP basic knowledge

- The Precision Time Protocol (PTP) is a protocol used to synchronize clocks in a network.
- The actual implementation of the protocol is known as linuxptp, a PTPv2 implementation according to the *IEEE standard 1588* for Linux.
- The linuxptp package includes the ptp4l and phc2sys programs for clock synchronization.
  - The ptp4l program implements the PTP boundary clock and ordinary clock. With hardware time stamping, it is used to synchronize the PTP hardware clock to the master clock, and with software time stamping it synchronizes the system clock to the master clock.
  - The phc2sys program is needed only with hardware time stamping, for synchronizing the system clock to the PTP hardware clock on the network interface card (NIC).
  - https://access.redhat.com/documentation/en-us/red_hat_enterprise_linux/6/html/deployment_guide/ch-configuring_ptp_using_ptp4l

Linux PTP for S-Plane

PTP best effort and Grand Master

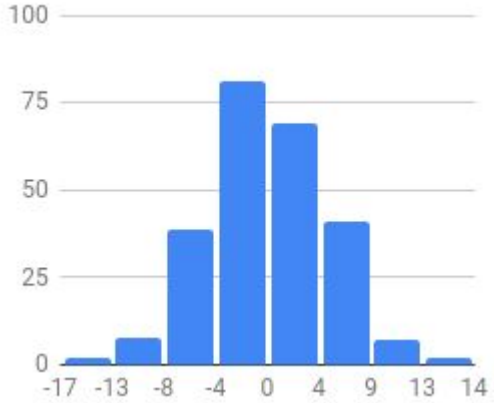
- Eurecom's setup uses the best effort synchronization
  - The DU machine is considered as the Master
  - PTP usage in HW mode (PTP4L + PHC2SYS)
- Future improvement will be
  - Employ the PTP Grand Master
    - External HW component connected to GPS antenna that provides the clock timing information to the whole Network
      - Both for DU server and RU server
    - The slaves are synchronized to their masters which may be slaves to their own masters.

Linux PTP for S-Plane

Offset from master clock - Eurecom's setup

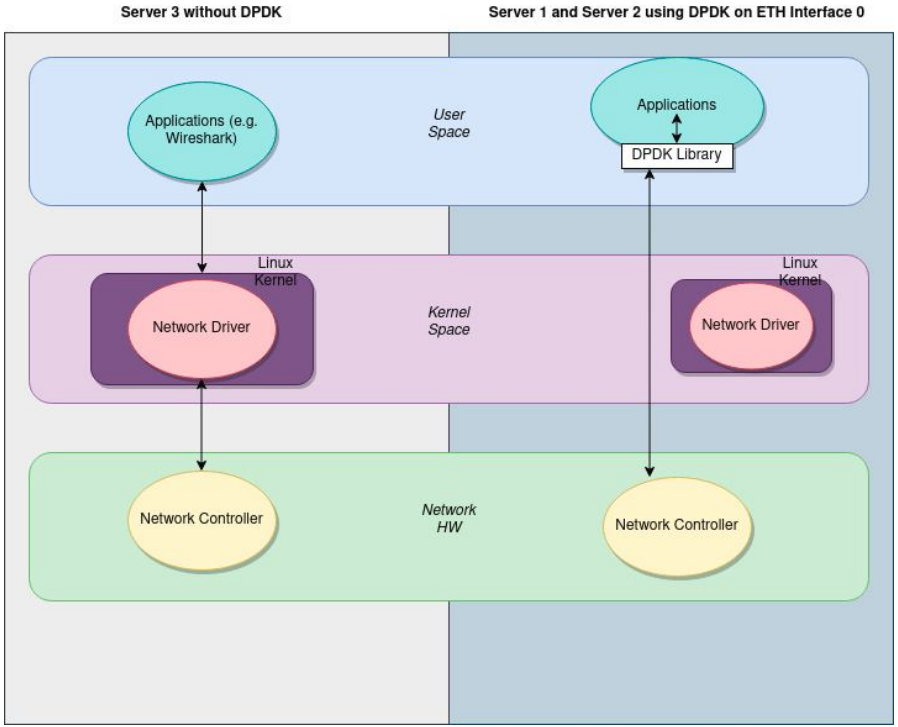
Graph in slide 7 shows the convergence of the Offset from the master clock of the RU slave machine

- https://docs.google.com/spreadsheets/d/10f6k6ANJzqNX6BI8Ij6UBaamnogICgqh/edit?usp=sharing&ouid=108559772115846854883&rtpof=true&sd=true



Moyenne	0,03212851406
Médiane	0
Valeur minimale	-17
Valeur maximale	13

OAI O-DU Wireshark measurement and DPDK



- Server 1 and 2 for O-DU and O-RU use xRAN library + DPDK library
  - Bypass linux kernel, prevent bottlenecks in packet processing
  - Efficient use of the 10G Network Interface
  - If DPDK binded to an ETH port it is not possible to use wireshark for the inspection
- Server 3 dumps packets with wireshark
  - Network spoofing application monitoring packets processed by the kernel
  - Acts as a switch to forward packets

https://blog.selectel.com/introduction-dpdk-architecture-principles/

Xilinx T1 card project

https://hackmd.io/UHUedMW2SB6oBfugROqTkw?view