IP Infusion's RAN Transport Fronthaul Switch

Application Note

Overview

Before the advent of the 5G era, the base station (RAN) consisted of three parts:

- Antenna
- RRU (radio-frequency pull-out unit)
- BBU (baseband processing unit)

The RU is used to transmit and receive signals, while BBU is used to process signaling messages. In the era preceding 3G, RRU+ BBU, power supply units and other equipment were placed in one cabinet, which was somewhat a bloated deployment.

In the 3G era, distributed base stations were proposed.

- BBU can be separated from RRU
- RRU can even be hung under the antenna, instead of being in the same cabinet with BBU

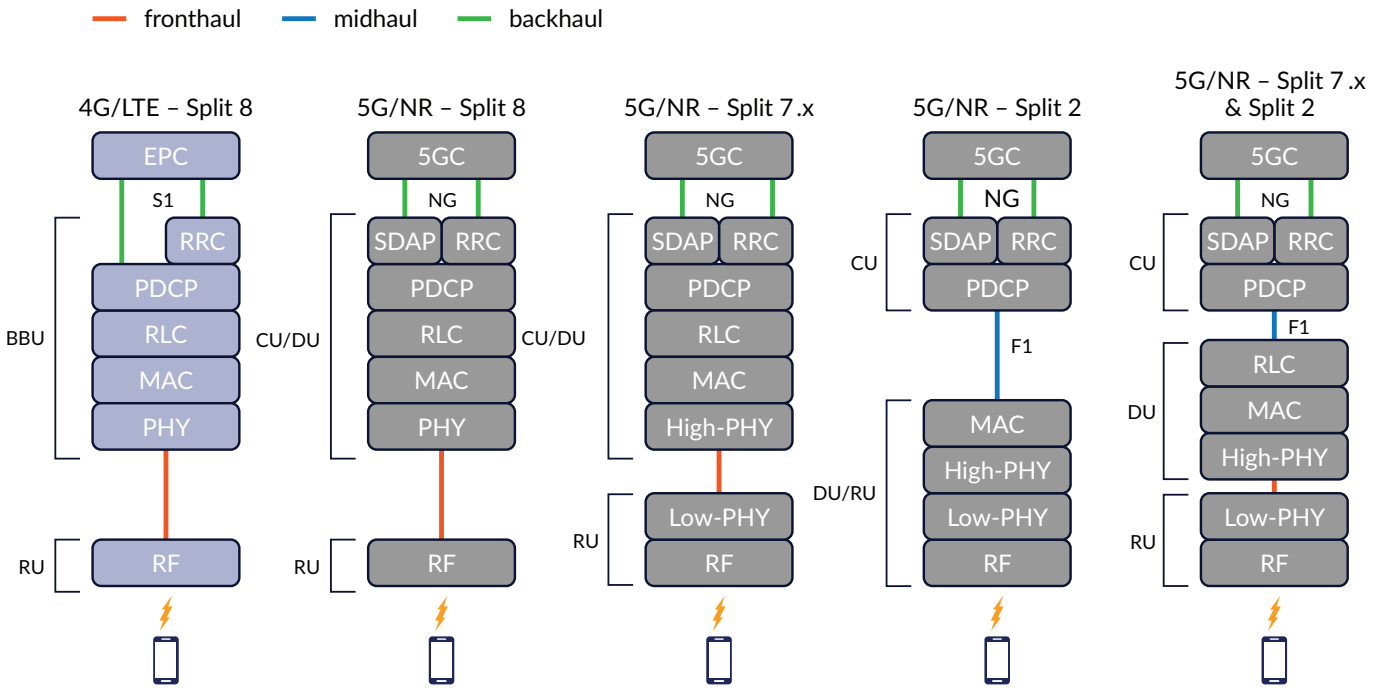
This is called D-RAN or Distributed-RAN and is the predominant 4G deployment architecture.

Technological improvements have enabled Centralized RAN (C-RAN) which has been introduced in 4G and is being used with 5G legacy vendor deployments.

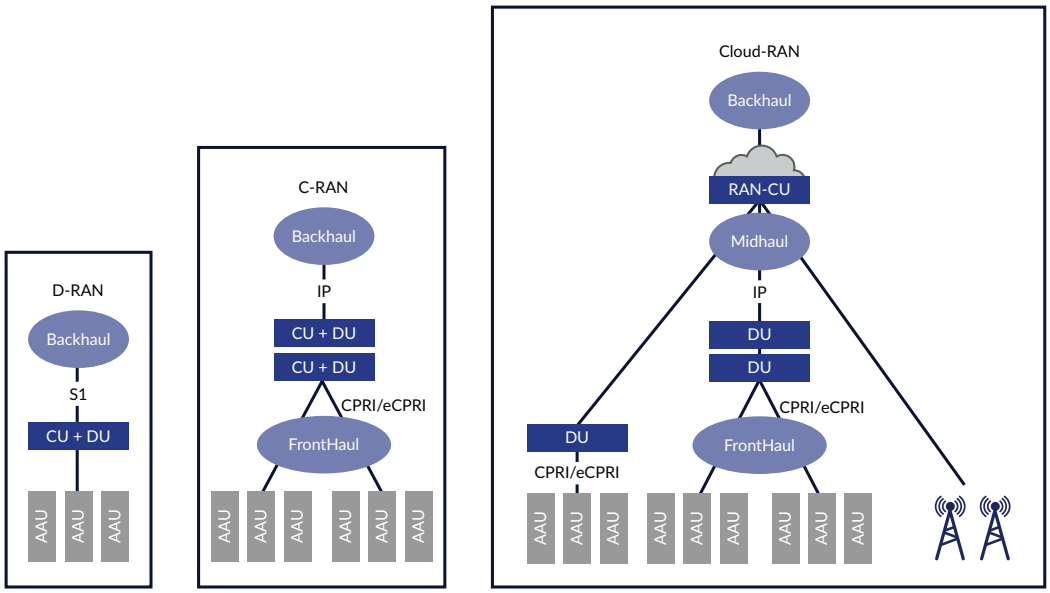
- The separation scheme between BBU and RRU is still adopted, but RRU is infinitely close to the antenna, which greatly reduces the attenuation through the feeder (the connection between antenna and RRU)
- Meanwhile, BBU is migrated and concentrated in the CO or more recently the CORD (Central Office Rearchitected as a Data Center) to form the BBU baseband pool, which is increasingly deployed using NFV. The CO and RRU are connected through the prequel network
- This is very conducive to inter-cell cooperation, reduce the transmission caused by attenuation, saving costs
- This is also more efficient than D-RAN in terms of resource utilization where any BBU in the pool can serve any RRU at the site

Further advancement was made in 5G, where the BBU's were split into Distributed Unit (DU) and Centralized Unit (CU). DU's placement was analogous to the BBU pool and connected via fronthaul to the RRU's where as CUs were connected to the DU's via the mid-haul and to the Core via the backhaul.

The evolution of functional split from Centralized-RAN to Cloud-RAN is shown in the figure below.



The network architecture evolution showing different components is depicted in the figure below:



This centralized wireless access has given rise to the deployment of C-RAN Hub sites where baseband units for centralized and Cloud RAN are deployed. With the migration from dedicated hardware to NFV-based deployment, this pool of virtual baseband units or vBBUs requires the fronthaul traffic to be aggregated for transport into the pool, where it is processed and then sent via midhaul to a regional core (CU and EPC), or via backhaul (where the vBBUs consist of vDU and vCU) to the regional EPC.

The resulting implementation expands the RAN transport domains as follows:

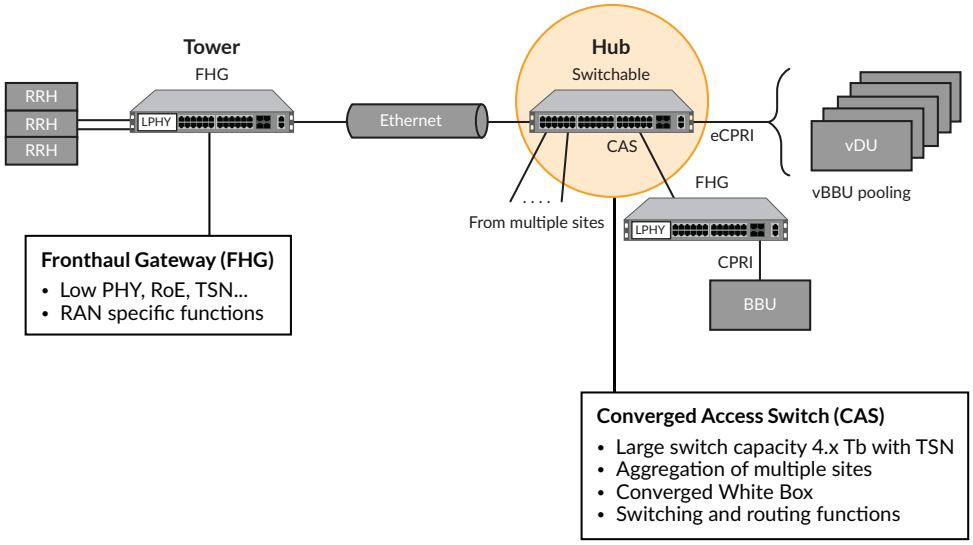
- Fronthaul (FH) – The transport segment between the radio unit (RU) and the distributed unit (DU)
- Midhaul (MH) – The transport segment between the DU and the centralized unit (CU)
- Backhaul (BH) – The transport segment between the CU and the evolved packet core (EPC)

The enabling technologies are RoE (IEEE 1914.3-2018 Radio over Ethernet) and eCPRI (enhanced Common Public Ration Interface) which provides for efficient and flexible rad data transmission via packet-based fronthaul network like IP or Ethernet. The advantages of RoE and eCPRI are:

- 10x reduction of required bandwidth
- Required bandwidth can scale according to the to the user plane traffic
- Ethernet can carry RoE, eCPRI, other transport traffic simultaneously, in the same switched network
- A single Ethernet network can simultaneously carry RoE and eCPRI traffic from several system vendors
- Ethernet-OAM may be used for operation, administration, maintenance, provisioning, and troubleshooting of the network
- The new interface is a real-time traffic interface enabling use of sophisticated coordination algorithms guaranteeing best possible radio performance
- The interface is future proof allowing new feature introductions by SW updates in the radio network
- Jitter and latency will be reduced for high priority traffic using Time Sensitive Networking standard IEEE 802.1CM. The 802.1CM supports preemption of a low priority packet to schedule a high priority delay and jitter sensitive transmission

This transport architecture is applicable to both C-RAN deployments and the newer Open RAN (O-RAN) deployments, making this use case ubiquitous, irrespective of the radio access network implementation as RoE and eCPRI as well as open radio interfaces, make it easier for carriers to mix and match vendor equipment for their RUs and DUs and aggregate the radio traffic for baseband processing.

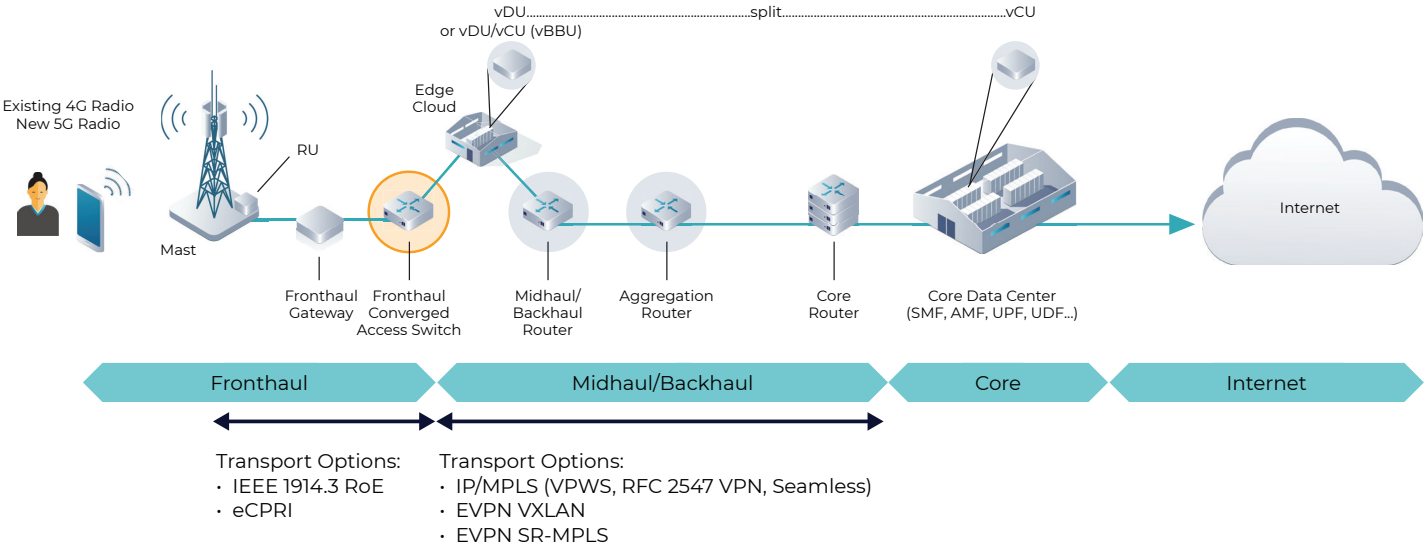
A fronthaul gateway is used to map legacy CPRI and ROE into eCPRI enabling a single packetized interface that can be framed in Ethernet to take advantage the capabilities of switched and/or routed network technology. The Fronthaul Converged Access Switch (FH-CAS) is used to aggregate multiple radio sites into the vBBU pools as shown in the figure below:



IP Infusion's transport Fronthaul Switching Solution for C-RAN

IP Infusion's RAN Transport Fronthaul Switching solution addresses the needs of the C-RAN Hub as well as those of O-RAN deployments where the number of physical lines between the O-RU and O-DU needs to take on network topologies other than point-to-point where there is a need for a Layer 2 switch. O-RAN refers to this function as the Hub Site Router (HSR).

This functionality is reflected in the IP Infusion RAN Transport solution as follows:



The scope of this application note describes the deployment of the C-RAN Hub and O-RAN HSR and O-RAN CSR using L2 switching or an L2 Overlay network. As the networks continue to evolve, it is expected that L3 routing will also be deployed as part of these functions.

The following technologies are used to enable the C-RAN Hub and O-RAN HSR function using L2 switching:

- ELINE – Either local switched ELINE or EVPN based ELINE.
- SyncE and IEEE 1588 PTP Timing
- QoS
- Time-Sensitive Network (TSN)
- CFM/Y.1731 OAM

We will further discuss the Ethernet Xconnect and SyncE/1588 PTP timing requirements to enable the C-RAN Hub and O-RAN HSR as part of this Application Note. This represents the minimum requirements to transport native eCPRI and RoE 1914.3 traffic. Time Sensitive Networking (TSN) and Connectivity Fault Management (CFM/Y.1731), once enabled in the application can also be used to realise the functionality, though they are outside the current scope of this Application Note.

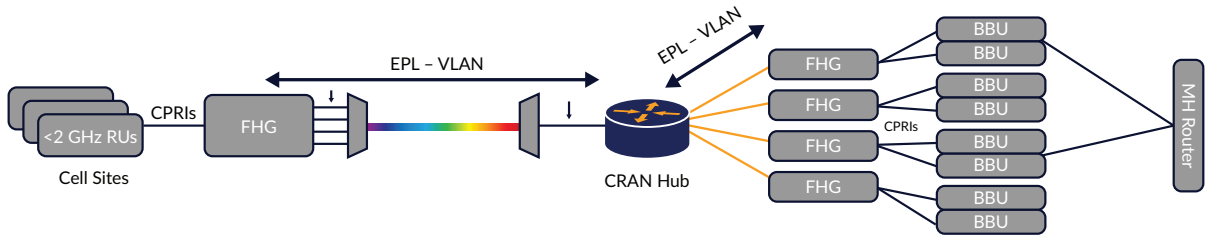
This application has been validated on platforms based on Qumran AX and Qumran 2c chipsets. Where future needs drive the use of TSN, then platforms based on the Qumran 2c/2a/2u family of chipsets will be required to implement this application.

For TSN and Fronthaul Gateway (FHG), explicit hardware support is required. Hardware platform vendors are working on making the support available. Once disaggregated hardware platforms have this support available, OcNOS support will be extended to deliver the services using the same.

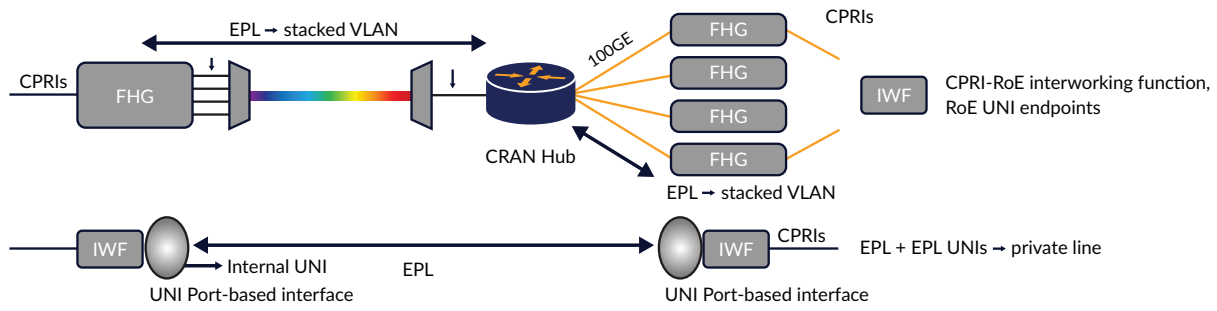
C-RAN Hub Use Cases

Use Case 1: Addressing Fronthaul for legacy RUs and BBUs

The base solution to address fronthaul for legacy RUs and BBUs with or without DSS is shown in the figure below:



An EPL-to-EPL Xconnect provides the required interworking function for this application as shown in the figure below:



Sample Configuration example to enable EPL-to- EPL Interworking:

Topology:

CRAN Hub

Configuration Steps:

Configuration Command	Description
# conf t	Enter configure mode
(config)#interface ce2	Configure interface port ce2
(config-if)#dot1ad ethertype 0x88a8	Set the port ethertype to 0x88a8 (802.1ad)
(config-if)#interface ce2.1 switchport	Configure the switchport interface on the port
(config-if)#encapsulation default	Set the switchport encapsulation to default
(config)#interface ce3	Configure interface port ce2
(config-if)#dot1ad ethertype 0x88a8	Set the port ethertype to 0x88a8 (802.1ad)
(config-if)#interface ce3.1 switchport	Configure the switchport interface on the port
(config-if)#encapsulation default	Set the switchport encapsulation to 8021.ad
(config-if)#exit	Exit interface configuration mode
(config)#cross-connect EPL-1	Configure the Ethernet Xconnect between ce2.1 and ce3.1
(config-xc)#interface ce2.1	
(config-xc)#interface ce3.1	
(config)# commit	Commit the configuration changes

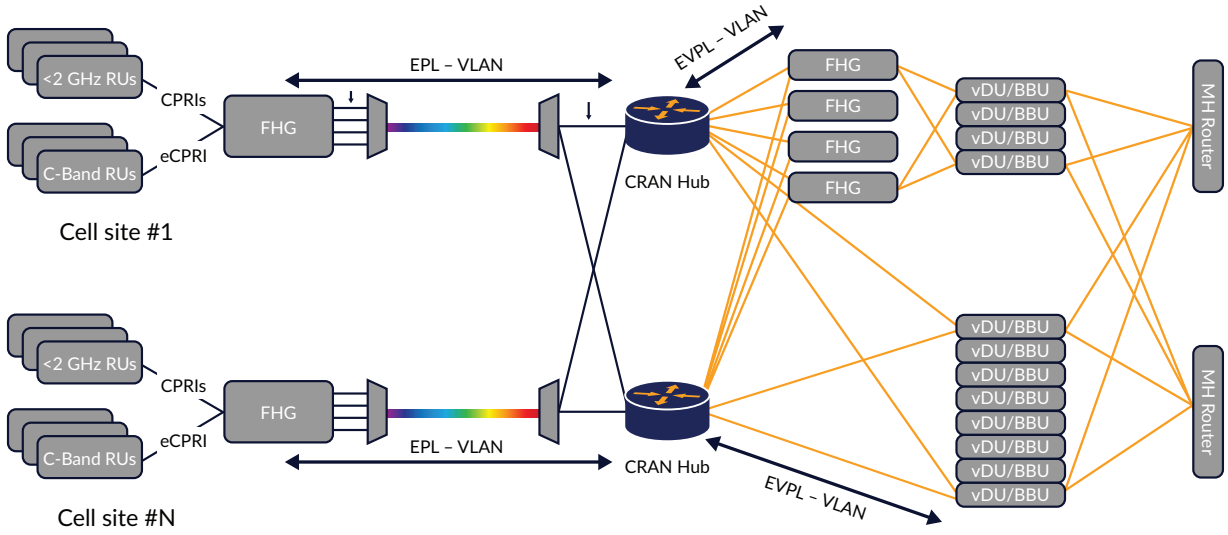
Validation Steps:

```
CRAN-A#show running-config interface
interface ce2
 description UNI-1
 dot1ad ethertype 0x88a8
!
interface ce2.1 switchport
 encapsulation default
!
interface ce3
 description NNI-1
 dot1ad ethertype 0x88a8
!
interface ce3.1 switchport
 encapsulation default
```

```
CRAN-A#sho int subinterfaces
-------------------------------------------------------------------------------
interface     | Encaptag1          | Encaptag2          | Action
              | type    vlan       | type    vlan       |
-------------------------------------------------------------------------------
ce2.1         | default            |                    |
ce3.1         | default            |                    |

CRAN-A##sho cross-connect
cross-connect status
XC name                          Ep1               Ep2               Status
-------------------------------+-----------------+-----------------+-------
EPL-1                          ce2.1           ce3.1           UP
-------------------------------+-----------------+-----------------+-------
AC cross-connect summary
Total : 1
Up    : 1
Down  : 0

CRAN-A#sho int counters summary
+-------------+--------------------+--------------------+--------------------+--------------------
-+
|  Interface  |     Rx packets     |      Rx bytes      |     Tx packets     |
    Tx bytes      |
+-------------+--------------------+--------------------+--------------------+--------------------
-+
 ce2.1         37                   2368                 0                    0
 ce3.1          0                   0                    37                   2368

CRAN-A#sho qos type cos-to-queue
profile name: default
profile type: cos-to-queue
configured mapping:
Detailed mapping:
---------------+---------------------------------  | ---------------+-----------------------------
---
      INPUT    |     OUTPUT                        |      INPUT     |     OUTPUT
---------------+---------------------------------  | ---------------+-----------------------------
---
   COS  |  DEI  | Queue |  Color  | Remark Queue  |   COS  |  DEI  | Queue |  Color  | Remark
Queue
--------+-------+-------+---------+-------------- | -------+-------+-------+---------------------
---
  0       0       0       green       0           |  0       1       0       yellow       0
  1       0       1       green       1           |  1       1       1       yellow       1
  2       0       2       green       2           |  2       1       2       yellow       2
  3       0       3       green       3           |  3       1       3       yellow       3
  4       0       4       green       4           |  4       1       4       yellow       4
  5       0       5       green       5           |  5       1       5       yellow       5
  6       0       6       green       6           |  6       1       6       yellow       6
  7       0       7       green       7           |  7       1       7       yellow       7
```

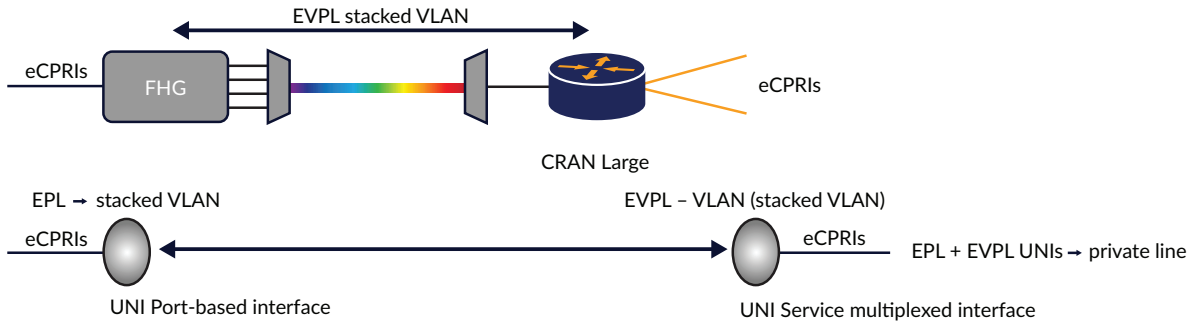
Use Case 2: Addressing Fronthaul for legacy RUs with standalone FHGW with the addition of Virtualized DU/BBU

Expanding the Base Solution to cover fronthaul for legacy RUs with stand-alone FHGW and vDU/BBU is shown in the figure below:



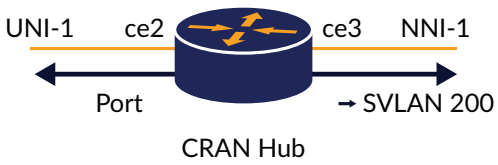
The architecture allows FHG that are already in service for LTE-A fronthaul to support 5G fronthaul such a C-band FH. The FHG at the CRAN Hub is used to enable migration from the legacy BBU to the vDU/BBU. This function can be external (shown) or integrated into the accelerator/BBU.

An EPL-to-EVPL interworking functions provides the required interworking function for this application as shown in the figure below:



Sample Configuration example to enable EPL-to- EVPL Interworking:

Topology:



Configuration Steps:

Configuration Command	Description
# conf t	Enter configure mode
(config)#interface ce2	Configure interface port ce2
(config-if)#dot1ad ethertype 0x88a8	Set the port ethertype to 0x88a8 (802.1ad)
(config-if)#interface ce2.200 switchport	Configure the switchport interface on the port
(config-if)#encapsulation default	Set the switchport encapsulation to default
(config-if)#rewrite push 0x88a8 200	Push VLAN 200 onto the outer tag (S-tag) on ingress, pop VLAN 200 from the outer tag on egress
(config)#interface ce3	Configure interface port ce2
(config-if)#dot1ad ethertype 0x88a8	Set the port ethertype to 0x88a8 (802.1ad)
(config-if)#interface ce3.200 switchport	Configure the switchport interface on the port
(config-if)#encapsulation dot1ad 200	Set the switchport encapsulation to 8021.ad
(config-if)#exit	Exit interface configuration mode
(config)#cross-connect EPL-200	Configure the Ethernet Xconnect between ce2.200 and ce3.200
(config-xc)#interface ce2.200	
(config-xc)#interface ce3.200	
(config)# commit	Commit the configuration changes

Validation Steps:

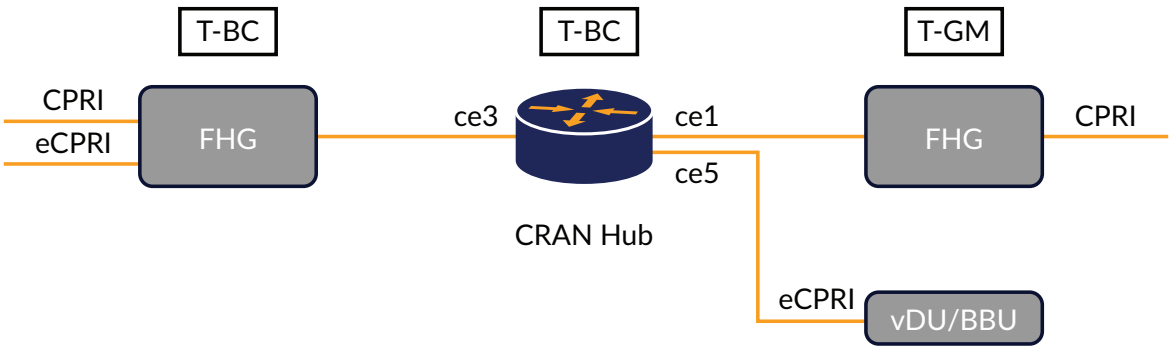
```
CRAN-A#show running-config interface
interface ce2
 description UNI-1
 dot1ad ethertype 0x88a8
!
interface ce2.200 switchport
 encapsulation default
 rewrite push 0x88a8 200
!
interface ce3
 description NNI-1
 dot1ad ethertype 0x88a8
!
interface ce3.200 switchport
 encapsulation dot1ad 200

CRAN-A#sho int subinterfaces
-------------------------------------------------------------------------------
interface    | Encaptag1          | Encaptag2          | Action
             | type    vlan       | type    vlan       |
-------------------------------------------------------------------------------
ce2.200      | default            |                    | push 0x88a8 200
ce3.200      | dot1ad  200        |                    |

CRAN-A##sho cross-connect
cross-connect status
XC name                         Ep1              Ep2              Status
------------------------------+----------------+----------------+-------
EPL-200                         ce2.200          ce3.200          UP
------------------------------+----------------+----------------+-------
AC cross-connect summary
Total : 1
Up    : 1
Down  : 0
```

```
CRAN-A#sho int counters summary
+-------------+-------------------+-------------------+-------------------+-------------------
+
|  Interface  |     Rx packets    |      Rx bytes     |     Tx packets    |    Tx bytes
|
+-------------+-------------------+-------------------+-------------------+-------------------
+
 ce2.200       82                  9924                0                   0
 ce3.200       0                   0                   82                  9924

CRAN-A#sho qos type cos-to-queue
profile name: default
profile type: cos-to-queue
configured mapping:
Detailed mapping:
---------------+--------------------------------- | ---------------+-------------------------------
     INPUT     |     OUTPUT                       |      INPUT     |     OUTPUT
---------------+--------------------------------- | ---------------+-------------------------------
   COS  |  DEI  | Queue |  Color  | Remark Queue |   COS  |  DEI  | Queue |  Color  | Remark Queue
-------+-------+-------+---------+------------- | -------+-------+-------+----------------------
--
  0       0       0       green       0          |  0       1       0       yellow       0
  1       0       1       green       1          |  1       1       1       yellow       1
  2       0       2       green       2          |  2       1       2       yellow       2
  3       0       3       green       3          |  3       1       3       yellow       3
  4       0       4       green       4          |  4       1       4       yellow       4
  5       0       5       green       5          |  5       1       5       yellow       5
  6       0       6       green       6          |  6       1       6       yellow       6
  7       0       7       green       7          |  7       1       7       yellow       7
```

Synchronization Timing

The CRAN Hub in this application is used as a Boundary Clock (T-BC) with the FHG as the Grand Master Clock (T-GM). Synchronous Ethernet (SyncE) is used to distribute the frequency from the primary reference clock to the downstream devices. IEEE 1588 Precision Time Protocol (PTP) is used provide Time-of-Day (ToD) as well as frequency and phase locked synchronization.

Topology



SyncE Configuration Steps

Configuration Command	Description
#conf t	Enter configure mode
(config)#synce	Enter configure Synchronous Ethernet mode
(config-synce)#synchronization option 1	Set the synchronization network type.
(config-synce)#clock-selection mode ql-enabled	Use the quality level as a criteria when selecting a clock
(config-synce)#exit	Exit configure Synchronous Ethernet mode
(config)#interface ce1	Configure interface ce1
(config-if)#synce	Enter interface Synchronous Ethernet mode
(config-if-synce)#mode synchronous	Configure synchronous mode
(config-if-synce)#input-source 1	Configure the interface as an input source with priority 2
(config-if-synce)#quality-level QL_PRC	Assign quality level as PRC
(config-if-synce)#exit	Enter interface Synchronous Ethernet mode
(config-if)#interface ce3	Configure interface ce3
(config-if-synce)#synce	Enter interface Synchronous Ethernet mode
(config-if-synce)#mode synchronous	Configure synchronous mode
(config-if-synce)#output-source	Configure the interface as an output source
(config-if-synce)#exit	Enter interface Synchronous Ethernet mode
(config-if)# exit	Enter interface mode
(config)# commit	Commit configuration

SyncE Validation Steps:

```
#show synce stats
Interface Name    Status    ESMC Received ESMC Sent
_______________   ______    _____________ _________
ce1               OK        0             0
ce3               Idle      0             91349

#show synce in
input-sources  interface
#sh synce input-sources
Interface Name           : ce1
ESMC Status              : OK
Is-selected-Source       : Yes
QL Configured           : QL_PRC
QL received in ESMC      : N/A
QL Operational           : QL_PRC
Priority                 : 1
Hold-off(ms)             : 300
Wait-to-restore(mins)    : 5
Link State               : Up
Signal Fail              : No
External Commands        : None
Clock-source-ID          : 256
WTR Timer Running        : No
Hold-off Timer Running   : No

#show synce output-sources
Interface Name  : ce3
Link State      : Up
QL Configured   : N/A
QL Operational  : QL_PRC
```

G.8275.1 Configuration Steps

Configuration Command	Description
#conf t	Enter configure mode
(config)#ptp clock profile g8275.1	Enables G8275.1 for PTP time/phase telecom profile
(config-ptp-clk)#domain 24	Set the current synchronization domain (for G.8275.1 the valid range is 24-43, 24 is default)
(config-ptp-clk)#number-ports 2	Configure the number of PTP ports on the instance
(config-ptp-clk)#local-priority 129	Specify the local clock priority
(config-ptp-clk)#priority2 156	Set the Priority2 attribute of the local clock
(config-ptp-clk)#clock-port 1	Configure ptp port
(config-clk-port)#network-interface ce1 dot1ad 1588	Configure underlying interface that is used by this PTP Port
(config-ptp-clk)#exit	Exit ptp clock port mode
(config-ptp-clk)#clock-port 2	Configure ptp port
(config-ptp-clk)#network-interface ce3 dot1ad 1588	Configure underlying interface that is used by this PTP Port
(config-ptp-clk)#exit	Exit ptp clock port modedeom

G.8275.1 Validation Steps

```
#sh synce output-sources
Interface Name  : ce3
Link State      : Up
QL Configured   : N/A
QL Operational  : QL_PRC

#sh ptp stats
clock 0:
  Number of ports             : 32
  Received Packets            : 24534403
  Discarded Packets           : 0
  Received IPv4 PTP Packets   : 0
  Received IPv6 PTP Packets   : 0
  Received L2 PTP Packets     : 24534403
  RX Queue Overflows          : 0
  Transmitted Packets         : 4310806

Port 1:
  Received Packets            : 12266348
  Discarded Packets           : 0
  Transmitted Packets         : 2155403

Port 2:
  Received Packets            : 12268055
  Discarded Packets           : 0
  Transmitted Packets         : 2155403

#sh ptp stats
clock 0:
  Number of ports             : 32
  Received Packets            : 24535629
  Discarded Packets           : 0
  Received IPv4 PTP Packets   : 0
```

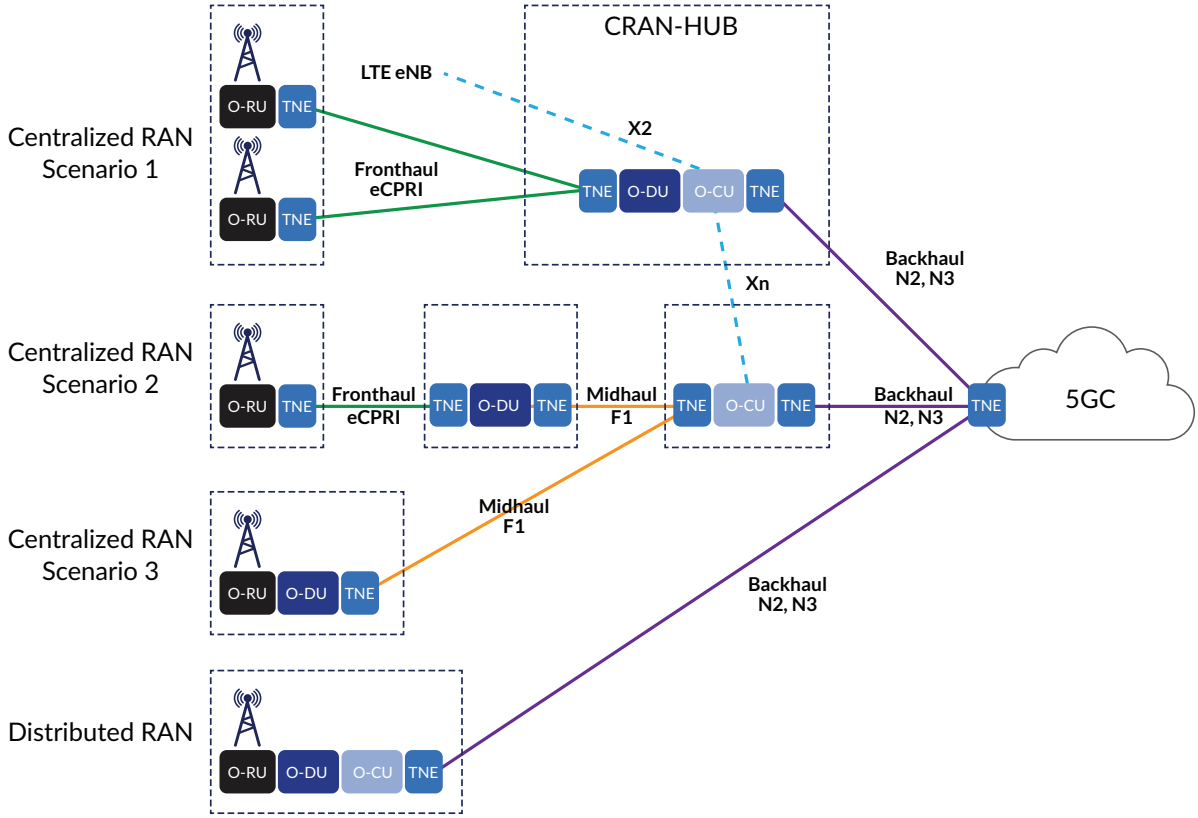
```
  Received IPv6 PTP Packets    : 0
  Received L2 PTP Packets      : 24535629
  RX Queue Overflows           : 0
  Transmitted Packets          : 4311018

Port 1:
  Received Packets             : 12266961
  Discarded Packets            : 0
  Transmitted Packets          : 2155509

Port 2:
  Received Packets             : 12268668
  Discarded Packets            : 0
  Transmitted Packets          : 2155509

#sh ptp stats
clock 0:
  Number of ports              : 32
  Received Packets             : 24536091
  Discarded Packets            : 0
  Received IPv4 PTP Packets    : 0
  Received IPv6 PTP Packets    : 0
  Received L2 PTP Packets      : 24536091
  RX Queue Overflows           : 0
  Transmitted Packets          : 4311100

Port 1:
  Received Packets             : 12267193
  Discarded Packets            : 0
  Transmitted Packets          : 2155550

Port 2:
  Received Packets             : 12268898
  Discarded Packets            : 0
  Transmitted Packets          : 2155550
```

O-RAN Fronthaul Switch Use Cases

O-RAN overview

With the advent of O-RAN, the centralized RAN components and interfaces are conceptualized and designed as open which enables operators to deploy end-to-end multi-vendor solution for both greenfield and brownfield implementations.

As per O-RANs Working Group (WG) 9 Transport requirement specifications, the reference architecture is as below:



O-RAN.WG-9.XTRP-REQ-v01.00

O-RAN suggests the use of 7-2x Split between O-RU, O-DU and O-CU and thus the xhaul is defined as below:

- Low Layer Split - Option 7 Split between O-RU and O-DU and the network between them is termed as Fronthaul. This is a split between low level and high level PHY and thus carries eCPRI traffic. It requires the network to be Layer2 native or an overlay Layer-2 provisioned.
- High Layer Split - Option 2 Split between O-DU and O-CU and the network between them is termed as Mid-haul. This is a split between the RLC and the PDCP layers and thus the midhaul can be realized as a Layer-3 Network.
- O-CU to 5GC/EPC – This realizes an N2/N3 interfaces defined by 3GPP and thus the network between them is termed as a backhaul network . This in most cases is a Layer-3 overlay network.

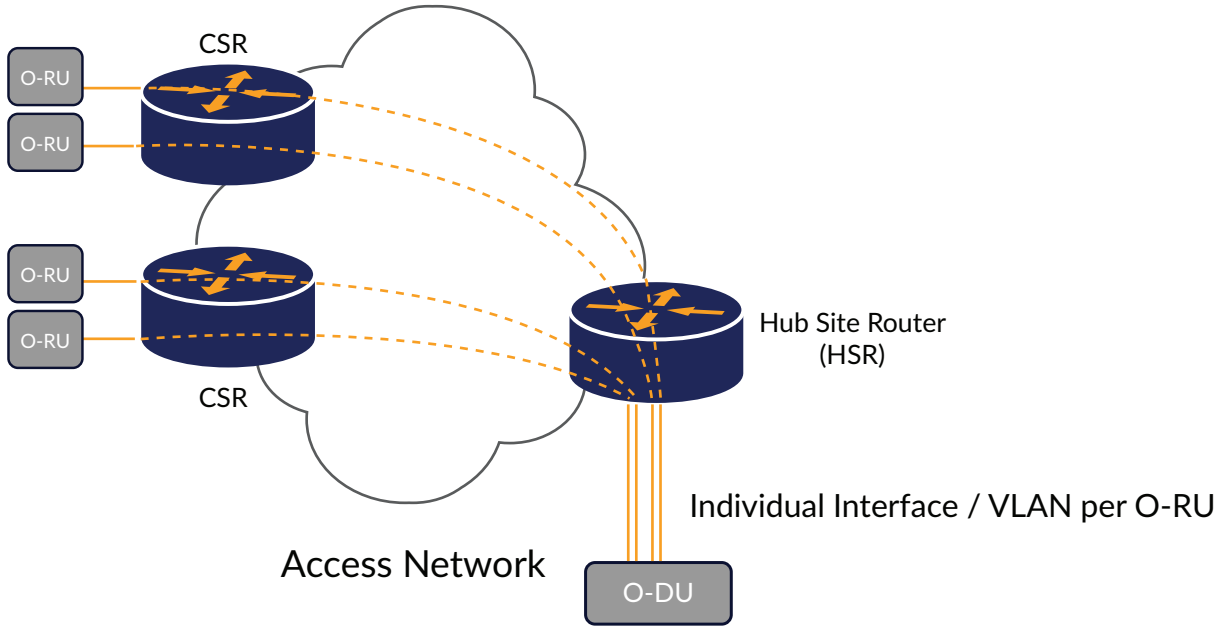
Fronthaul Network components

The requirements of the fronthaul network is to:

1. Enable layer-2 communication between O-RU and O-DU and provide conversion between CPRI/ RoE and eCPRI headers in order to support existing RAN networks and newer 5G O-RU's. This is called as the Control and User plane.
2. Provide end to end clock synchronization between O-DU and O-RU for ordered and timely delivery in both DL and UL directions. This is called as S-Plane.

3. Provisioning, management and operation of O-RU, O-DU , interfaces and protocols between them. This is called as M-Plane.

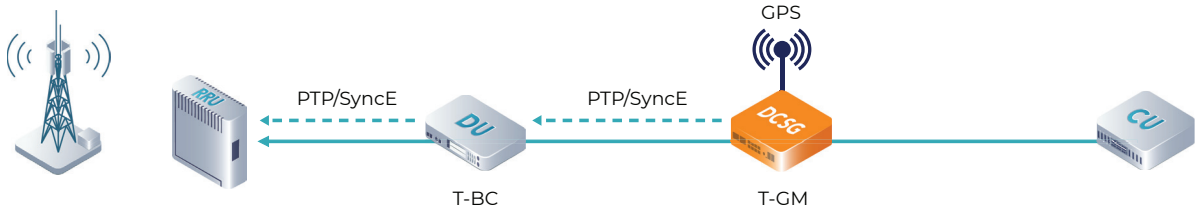
Based on the C and U Plane requirement, Fronthaul network can be realized using two components namely Cell Site Router (CSR) and Hub Site Router (HSR) with various Layer-2 implementations to support multipoint connectivity between O-RU and O-DU as shown in the figure below.



Multiple O-RU connectivity to a single O-DU via CSRs and HSR

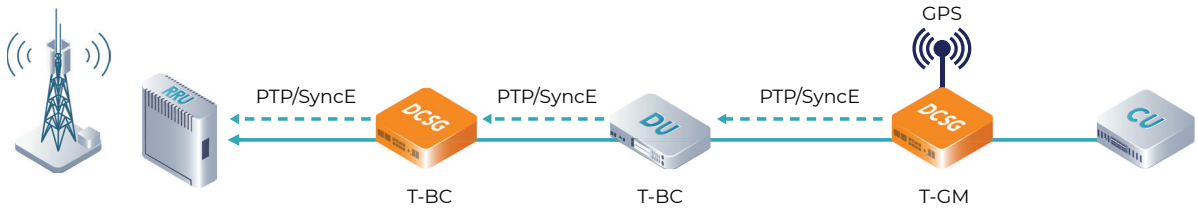
Based on S-Plane requirement, the Fronthaul network can have multiple configurations based on the placement options of PRTC/T-GM.

LLS-C1 – Low Layer Split C1 Option: This is a connectivity option where O-RU is directly connected to O-DU with no Network element in between. The O-DU either acts as the T-GM/PRTC or is locked to a Primary Reference and further provides synchronization to the O-RU.



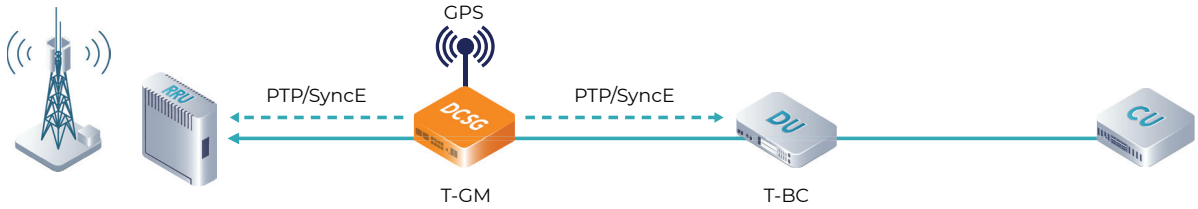
LLS-C1 configuration

LLS-C2 – Low Layer Split C2 Option: This is a connectivity option where O-RU and O-DU are connected via a Layer-2 fabric consisting of Network element(s). The O-DU either acts as a T-GM/PRTC or is locked and traceable to a Primary Reference and further provides synchronization to the O-RU.



LLS-C2 configuration

LLS-C3 – Low Layer Split C3 Option. This is a connectivity option which is similar to the LLS-C2 , except that the T-GM/PRTC resides inside the Layer-2 Fabric and thus provides synchronization to the O-DU and O-RU.



LLS-C3 configuration

IP Infusion's solution for Fronthaul Network

IP Infusion's OcNOS Solution has been proven and tested in the Fronthaul for Control Plane, User Plane and Synchronization Plane. It offers CSR and HSR network elements with various switching and transport capacities ranging from 64 Gbps to 320 Gbps.

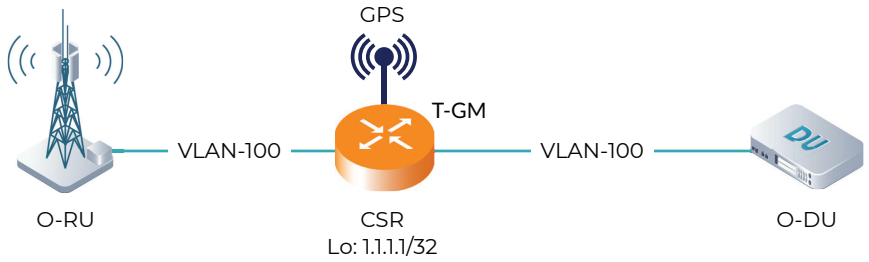
OcNOS also features various Layer-2 technologies and Timing/Synchronization profiles including:

- EVPN ELAN and ELINE with MPLS and VxLAN encapsulations
- Transport with MPLS encapsulations using LDP/RSVP and Segment Routing (for OSPFv2 and ISIS)
- QoS with Classification, strict and WFQ scheduling support and WRED for congestion avoidance
- SyncE and G.8275.1, G.8275.2 PTP profiles
- T-GM with GPS as primary source
- Other timing interfaces such as PPS In/Out, 10Mhz In/out etc.

O-RAN Fronthaul use case with OcNOS

Below topologies depicts CSR and HSR components of O-RAN fronthaul network using OcNOS and its various connectivity options. For both the use cases described below , only LLS-C3 configuration is considered where the network provides synchronization to the O-RU and O-DU.

Use Case 1 : O-DU and O-RU connected to same NE (CSR)



O-RU and O-DU are connected to the same CSR

For the above connectivity option, a simple layer-2 cross connect is provisioned for C and U plane and a T-GM is configured to synchronize both O-RU and O-DU.

Below configuration explains the connectivity for CU and M Plane communication.

```
CSR#config t
Enter configuration commands, one per line.  End with CNTL/Z.
CSR(config)#interface xe0.100 switchport
CSR(config-if)#description "to O-RU"
CSR(config-if)#encapsulation dot1q 100
CSR(config-if)#exit

CSR(config)#interface xe1.100 switchport
CSR(config-if)#description "to O-DU"
CSR(config-if)#encapsulation dot1q 100
CSR(config-if)#exit

CSR(config)#cross-connect RU-DU
CSR(config-xc)#interface xe0.100
CSR(config-xc)#interface xe1.100
CSR(config-xc)#exit

CSR#sho cross-connect
cross-connect status
XC name                        Ep1              Ep2              Status
-----------------------------+----------------+----------------+-------
RU-DU                          xe0.100          xe1.100          UP
-----------------------------+----------------+----------------+-------
AC cross-connect summary
Total : 1
Up    : 1
Down  : 0
CSR#
```

Below configuration explains the T-GM support and G.8275.1, SyncE to synchronize O-RU and O-DU.

SyncE Configuration

```
CSR(config)#synce
CSR(config-synce)#synchronization option 1
CSR(config-synce)#holdover 1440
CSR(config)#synce-interface gps
CSR(config-synce-if)#mode synchronous
CSR(config-synce-if)#input-source 1
CSR(config-synce-if)#quality-level QL_PRC
CSR(config-synce-if)#wait-to-restore 1
CSR(config)#interface xe0
CSR(config-synce-if)#synce
CSR(config-synce-if)#mode synchronous
CSR(config-synce-if)#input-source 10
CSR(config-synce-if)#output-source
CSR(config-synce-if)#wait-to-restore 1

CSR(config)#interface xe1
CSR(config-synce-if)#synce
CSR(config-synce-if)#mode synchronous
CSR(config-synce-if)#input-source 10
CSR(config-synce-if)#output-source
CSR(config-synce-if)#wait-to-restore 1

CSR#sho gps
GNSS Status:
  GNSS Fix      : Position Fix
  Latitude      : 12.975596 N
  Longitude     : 77.712601 E
  Altitude      : 924.4 Meters

GNSS Satellite Status:
  index  Type  PRN   C/No   Status  Azimuth Elevation
  1      GP    1     17     OK      270     34
  2      GP    10    33     OK      136     18
  3      GP    16    11     OK      167     43
  4      GP    26    33     OK      101     60
  5      GP    31    50     OK      22      35
  6      GP    32    48     OK      69      19
  7      GL    65    38     OK      96      26
  8      GL    66    47     OK      22      39
  9      GL    76    48     OK      25      44
  10     GL    81    18     OK      241     11
  11     GL    82    25     OK      286     4

GNSS Config:
  Position      : Survey-in
  Min Duration : 15 Minutes
  Accuracy      : 2000 cm

Survey-in Status:
```

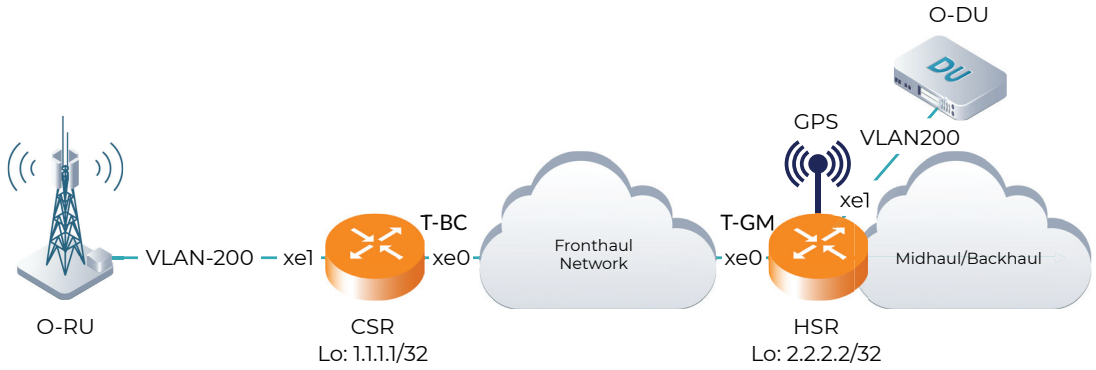
```
  Valid         : Yes
  Active        : No
  Duration      : 00:15:00
  Variance      : 36.06 cm

CSR#sho synce details
Equipment Clock       : EEC-option1
Interface Name        : gps
ESMC Status           : N/A
Is-selected-Source    : YES
QL               : QL_PRC
SyncE Clock State     : Locked
DPLL Clock State : Locked
Synce State Duration  : 17:27:52
Selected-Clk-Src-ID   : 256
10MHz Holdover Duration     : 1440 min
```

PTP G.8275.1 Configuration

```
CSR#config t
Enter configuration commands, one per line.  End with CNTL/Z.
CSR(config)#ptp clock profile g8275.1
CSR(config-ptp-clk)#number-ports 31
CSR(config-ptp-clk)#clock-port 1
CSR(config-clk-port)#network-interface gps
CSR(config-clk-port)#exit
CSR(config-ptp-clk)#clock-port 2
CSR(config-clk-port)#network-interface xe0
CSR(config-clk-port)#exit
CSR(config-ptp-clk)#clock-port 3
CSR(config-clk-port)#network-interface xe1
CSR(config-clk-port)#exit

CSR#sho ptp servo
PTP servo status for clock 0
  Servo Config                : Phase Correction
  Servo State                  : Normal Loop
  Servo State Duration         : 00:00:04
  Servo APTS Mode              : N/A
  Frequency Correction         : 0.000 ppb
  Phase Correction             : 0.000 nsec
  Offset From Master           : 0.000 nsec
  Mean Path Delay              : 0 nsec
  APTS GPS to PTP Offset       : 0 nsec
  Sync Packet Rate             : 0
  Delay Packet Rate            : 0
CSR#
CSR#
```

```
CSR#sho ptp clock dataset time-properties
  Current UTC Offset Valid    : True
  Current UTC Offset          : 37
  Leap 59                     : False
  Leap 61                     : False
  Time Traceable              : True
  Frequency Traceable         : True
  PTP Timescale               : True
  Time Source                 : Global positioning system
  Time of Day                 : Thu 21 Oct 2021 10:35:09 UTC
CSR#
```

Use Case 2 : O-DU and O-RU connected via Layer-2 Fabric



O-RU and O-DU are connected via a Layer-2 Fabric

The above connectivity option is provisioned as a layer-2 Fronthaul network which is implemented as an overlay EVPN ELINE configuration with MPLS encapsulation. The underlay is configured using Segment Routing MPLS in order to support slicing requirements for different nature of 5G services.

This network also provides clock synchronization to both O-DU and O-RU to meet the end to end S-Plane requirements between O-RU, O-DU and Fronthaul components.

Below configuration provides the underlay using ISIS as the IGP and SR MPLS for end to end LSP.

Note: Configuration snippet provided for CSR box. Similar configurations are applicable for the HSR with different IP address assignments and PfxSIDs.

```
CSR(config)#
CSR(config)#router isis 1
CSR(config-router)#is-type level-1
CSR(config-router)#net 49.0001.0000.0000.0001.00
CSR(config-router)#metric-style wide
CSR(config-router)#mpls traffic-eng level-1
CSR(config-router)#mpls traffic-eng router-id 1.1.1.1
CSR(config-router)#dynamic-hostname
CSR(config-router)#segment-routing mpls
CSR(config-router)#passive-interface lo
CSR(config-router)#passive-interface lo
CSR(config-router)#exit
!
CSR(config)#interface xe0
CSR(config-if)#ip router isis 1
CSR(config-if)#isis network point-to-point
!
CSR#config t
Enter configuration commands, one per line.  End with CNTL/Z.
CSR(config)#interface lo
CSR(config-if)#prefix-sid index 1
CSR(config-if)#end

CSR#sho clns neighbors

Total number of L1 adjacencies: 1
Total number of L2 adjacencies: 0
Total number of adjacencies: 1
Tag 1:  VRF : default
System Id      Interface   SNPA            State  Holdtime  Type Protocol
HSR            xe0         80a2.3572.3015  Up     27        L1   IS-IS
CSR#sho ip route
Codes: K - kernel, C - connected, S - static, R - RIP, B - BGP
       O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2,
       ia - IS-IS inter area, E - EVPN,
       v - vrf leaked
       * - candidate default

IP Route Table for VRF "default"
C            1.1.1.1/32 is directly connected, lo, 01w0d04h
i L1         2.2.2.2/32 [115/10] via 10.12.1.2, xe0, 00:01:13
C            10.12.1.0/30 is directly connected, xe0, 00:01:15
C            127.0.0.0/8 is directly connected, lo, 01w0d04h

Gateway of last resort is not set
```

```
CSR#sho mpls forwarding-table
Codes: > - installed FTN, * - selected FTN, p - stale FTN,
       B - BGP FTN, K - CLI FTN, t - tunnel, P - SR Policy FTN,
       L - LDP FTN, R - RSVP-TE FTN, S - SNMP FTN, I - IGP-Shortcut,
       U - unknown FTN, O - SR-OSPF FTN, i - SR-ISIS FTN, k - SR-CLI FTN

Code    FEC                FTN-ID    Nhlfe-ID  Tunnel-id   Pri   LSP-Type
Out-Label    Out-Intf    ELC   Nexthop
   i>   2.2.2.2/32          1         2         0           Yes   LSP_DEFAULT  3
xe0         No    10.12.1.2
CSR#
```

Below configuration provides the MPLS EVPN ELINE as point to point Layer-2 overlay for communication between O-RU and O-DU.

Note: Configuration snippet provided for CSR box. Similar configurations will be done for the HSR.

```
CSR#config t
Enter configuration commands, one per line.  End with CNTL/Z.
CSR(config)#router bgp 100
CSR(config-router)#bgp router-id 1.1.1.1
CSR(config-router)#neighbor 2.2.2.2 remote-as 100
CSR(config-router)#neighbor 2.2.2.2 update-source lo
CSR(config-router)#address-family l2vpn evpn
CSR(config-router-af)#neighbor 2.2.2.2 ena
CSR(config-router-af)#neighbor 2.2.2.2 enaa
CSR(config-router-af)#neighbor 2.2.2.2 activate
CSR(config-router-af)#exit
CSR(config-router)#address-family vpnv4 unicast
CSR(config-router-af)#neighbor 2.2.2.2 activate
CSR(config-router-af)#end
!
CSR(config)#evpn mpls enable
%% System Reboot required, please save the config and reboot the board.
CSR(config)#
!
CSR(config)#mac vrf RU-DU
CSR(config-vrf)#rd 1.1.1.1:1002
CSR(config-vrf)#route-target both 1002:1002
CSR(config-vrf)#
!
CSR(config)#
CSR(config)#evpn mpls vtep-ip-global 1.1.1.1
CSR(config)#evpn mpls id 1 xconnect target-mpls-id 2
CSR(config-evpn-mpls)#host-reachability-protocol evpn-bgp RU-DU
!
CSR(config)#interface xe1.200 switchport
CSR(config-if)#mtu 9216
% Warning: Subinterface MTU Changed, Update the Parent MTU greater than or
equal to 9216.
```

```
CSR(config-if)#encapsulation dot1q 200
CSR(config-if)#access-if-evpn
CSR(config-acc-if-evpn)#map evpn mpls id 1
!

CSR#sho bgp l2vpn evpn summary
BGP router identifier 1.1.1.1, local AS number 100
BGP table version is 22
1 BGP AS-PATH entries
0 BGP community entries

Neighbor                 V    AS    MsgRcv    MsgSen TblVer    InQ    OutQ    Up/
Down    State/PfxRcd     AD  MACIP  MCAST     ESI  PREFIX-ROUTE
2.2.2.2                   4    100 24264      24268      22       0       0
00:29:50               2       2       0       0       0       0

Total number of neighbors 1

Total number of Established sessions 1
CSR#

CSR#sho evpn mpls xconnect tunnel
EVPN-MPLS Network tunnel Entries
Source           Destination      Status        Up/Down       Update        lo-
cal-evpn-id remote-evpn-id
================================================================================
========================
1.1.1.1          2.2.2.2          Installed     00:29:20      00:29:20      1
2


CSR#sho evpn mpls xconnect
EVPN-MPLS Xconnect Info
=======================
AC-AC: Local-Cross-connect
AC-NW: Cross-connect to Network
AC-UP: Access-port is up
AC-DN: Access-port is down
NW-UP: Network is up
NW-DN: Network is down
NW-SET: Network and AC both are up

Local                            Remote       Connection-Details
================================ ============ ================================
================================================
VPN-ID       EVI-Name       MTU   VPN-ID       Source       Destination
PE-IP           MTU   Type   NW-Status
================================ ============ ================================
================================================
1            ----           9216  2            xe1.200      --- Single Homed
Port ---     2.2.2.2          9216  AC-NW  NW-SET

Total number of entries are 1
```

Below configuration shows the provisioning of SyncE, PTP G8275.1 and GPS on HSR acting as T-GM to synchronize O-DU and the Fronthaul Network.

SyncE Configuration

```
HSR(config)#synce
HSR(config-synce)#synchronization option 1
HSR(config)#synce-interface gps
HSR(config-synce-if)#mode synchronous
HSR(config-synce-if)#input-source 1
HSR(config-synce-if)#quality-level QL_PRC
HSR(config-synce-if)#wait-to-restore 1
!
HSR(config)#interface xe0
HSR(config-synce-if)#synce
HSR(config-synce-if)#mode synchronous
HSR(config-synce-if)#input-source 10
HSR(config-synce-if)#output-source
HSR(config-synce-if)#wait-to-restore 1
!
HSR(config)#interface xe1
HSR(config-synce-if)#synce
HSR(config-synce-if)#mode synchronous
HSR(config-synce-if)#input-source 20
HSR(config-synce-if)#output-source
HSR(config-synce-if)#wait-to-restore 1

HSR#sho gps
GNSS Status:
  GNSS Fix      : Position Fix
  Latitude      : 12.975596 N
  Longitude     : 77.712601 E
  Altitude      : 924.4 Meters

GNSS Satellite Status:
  index  Type  PRN   C/No   Status  Azimuth Elevation
  1      GP    1     17     OK      270     34
  2      GP    10    33     OK      136     18
  3      GP    16    11     OK      167     43
  4      GP    26    33     OK      101     60
  5      GP    31    50     OK      22      35
  6      GP    32    48     OK      69      19
  7      GL    65    38     OK      96      26
  8      GL    66    47     OK      22      39
  9      GL    76    48     OK      25      44
  10     GL    81    18     OK      241     11
  11     GL    82    25     OK      286     4

GNSS Config:
  Position      : Survey-in
  Min Duration : 15 Minutes
  Accuracy      : 2000 cm
```

```
Survey-in Status:
  Valid         : Yes
  Active        : No
  Duration      : 00:15:00
  Variance      : 36.06 cm

HSR#sho synce details
Equipment Clock       : EEC-option1
Interface Name        : gps
ESMC Status           : N/A
Is-selected-Source    : YES
QL              : QL_PRC
SyncE Clock State     : Locked
DPLL Clock State : Locked
Synce State Duration  : 17:27:52
Selected-Clk-Src-ID   : 256
10MHz Holdover Duration     : 1440 min
```

PTP G.8275.1 Configuration

```
HSR#config t
Enter configuration commands, one per line.  End with CNTL/Z.
HSR(config)#ptp clock profile g8275.1
HSR(config-ptp-clk)#number-ports 31
HSR(config-ptp-clk)#clock-port 1
HSR(config-clk-port)#network-interface gps
HSR(config-clk-port)#exit
HSR(config-ptp-clk)#clock-port 2
HSR(config-clk-port)#network-interface xe0
HSR(config-clk-port)#exit
HSR(config-ptp-clk)#clock-port 3
HSR(config-clk-port)#network-interface xe1
HSR(config-clk-port)#exit

HSR#sho ptp servo
PTP servo status for clock 0
  Servo Config                : Phase Correction
  Servo State                  : Normal Loop
  Servo State Duration         : 00:00:04
  Servo APTS Mode              : N/A
  Frequency Correction         : 0.000 ppb
  Phase Correction             : 0.000 nsec
  Offset From Master           : 0.000 nsec
  Mean Path Delay              : 0 nsec
  APTS GPS to PTP Offset       : 0 nsec
  Sync Packet Rate             : 0
  Delay Packet Rate            : 0
HSR#
HSR#
```

```
HSR#sho ptp clock dataset time-properties
  Current UTC Offset Valid    : True
  Current UTC Offset          : 37
  Leap 59                     : False
  Leap 61                     : False
  Time Traceable              : True
  Frequency Traceable         : True
  PTP Timescale               : True
  Time Source                 : Global positioning system
  Time of Day                 : Thu 21 Oct 2021 10:35:09 UTC
HSR#
```

Below configuration shows the provisioning of SyncE, PTP G8275.1 and GPS on CSR acting as T-BC to synchronize O-RU.

SyncE Configuration

```
CSR(config)#synce
CSR(config-synce)#synchronization option 1
CSR(config)#interface xe0
CSR(config-synce-if)#synce
CSR(config-synce-if)#mode synchronous
CSR(config-synce-if)#input-source 1
CSR(config-synce-if)#output-source
CSR(config-synce-if)#wait-to-restore 1
!
CSR(config)#interface xe1
CSR(config-synce-if)#synce
CSR(config-synce-if)#mode synchronous
CSR(config-synce-if)#input-source 10
CSR(config-synce-if)#output-source
CSR(config-synce-if)#wait-to-restore 1


CSR#sho synce details
Equipment Clock       : EEC-option1
Interface Name        : xe0
ESMC Status           : Active
Is-selected-Source    : YES
QL              : QL_PRC
SyncE Clock State     : Locked
DPLL Clock State : Locked
Synce State Duration  : 17:29:52
Selected-Clk-Src-ID   : 256
10MHz Holdover Duration     : 1440 min
```

PTP G.8275.1 Configuration

```
CSR#config t
Enter configuration commands, one per line.  End with CNTL/Z.
CSR(config)#ptp clock profile g8275.1
```

```
CSR(config-ptp-clk)#number-ports 31
CSR(config-ptp-clk)#clock-port 1
CSR(config-clk-port)#network-interface xe0
CSR(config-clk-port)#exit
CSR(config-ptp-clk)#clock-port 3
CSR(config-clk-port)#network-interface xe1
CSR(config-clk-port)#exit

CSR#sho ptp servo
PTP servo status for clock 0
  Servo Config                : Phase Correction
  Servo State                 : Normal Loop
  Servo State Duration        : 00:00:04
  Servo APTS Mode             : N/A
  Frequency Correction        : 0.000 ppb
  Phase Correction            : 0.000 nsec
  Offset From Master          : 0.000 nsec
  Mean Path Delay             : 0 nsec
  APTS GPS to PTP Offset      : 0 nsec
  Sync Packet Rate            : 0
  Delay Packet Rate           : 0
CSR#
CSR#

CSR#sho ptp clock dataset time-properties
  Current UTC Offset Valid    : True
  Current UTC Offset          : 37
  Leap 59                     : False
  Leap 61                     : False
  Time Traceable              : True
  Frequency Traceable         : True
  PTP Timescale               : True
  Time Source                 : Global positioning system
  Time of Day                 : Thu 21 Oct 2021 10:35:09 UTC
CSR#
```

ABOUT IP INFUSION

IP Infusion, a leader in disaggregated networking solutions, delivers enterprise and carrier-grade software solutions allowing network operators to reduce network costs, increase flexibility, and to deploy new features and services quickly. IP Infusion is headquartered in Santa Clara, Calif., and is a wholly owned and independently operated subsidiary of ACCESS CO., LTD. Additional information can be found at **http://www.ipinfusion.com**

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