# TUTORIAL

## O-RAN FUNDAMENTALS

## SYNCHRONIZATION OVERVIEW

WORKSHOP ON SYNCHRONIZATION AND TIMING SYSTEMS
MAY 9-12, 2022 | DENVER, CO

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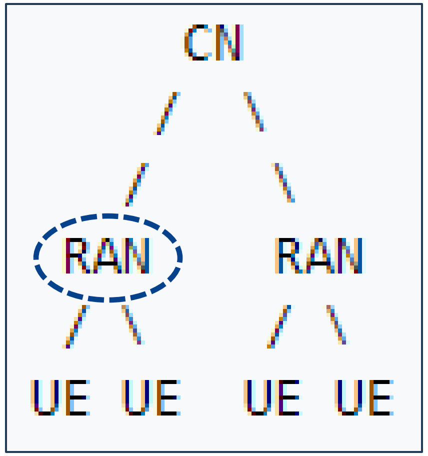
# OUTLINE

- What is O-RAN?
- O-RAN Overview
  - Functional Splits
  - Deployment
- Time Accuracy in eCPRI
  - Overview
  - O-RAN Synchronization Plane

# WHAT IS O-RAN

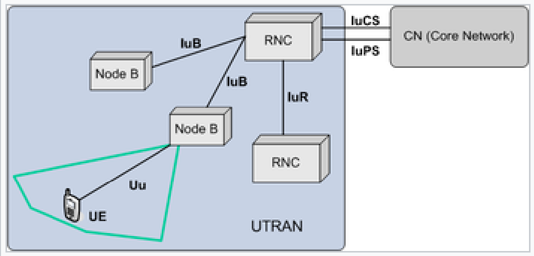
# First, What Is RAN ?

- **RAN = Radio Access Network**
  - It implements the radio access technology.
  - Resides between the User Equipment (UE) and the Core Network (CN)



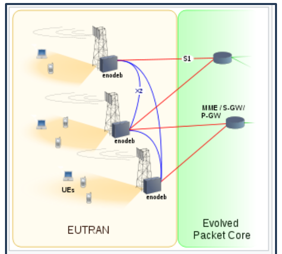

- **RAN history**
  - GRAN GSM Radio Access Network → 2G
    - TDMA, CDMA
  - UTRAN = UMTS Radio Access Network → 3G
    - W-CDMA radio access technology
  - E-UTRAN = Evolved UMTS Radio Access Network → 4G
    - MIMO, OFDM, Long Term Evolution (LTE) → 4G LTE
  - O-RAN = Open Radio Access Network → 5G
    - MIMO, mmWave, ESA (Beam Forming)
    - *Governed by IMT-2020 3GPP (3rd Generation Partnership)*

**Higher Speed**
**Lower Latency**



UTRAN architecture

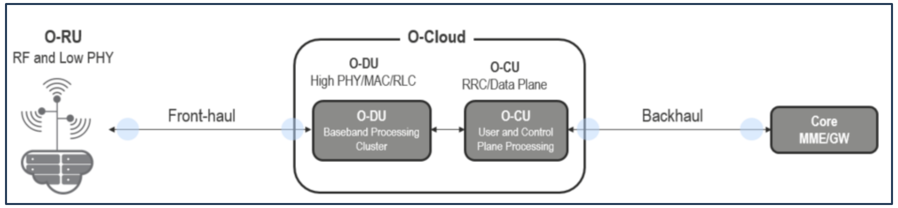
**UTRAN**



EUTRAN architecture as part of a LTE and SAE network

**E-UTRAN**

**O-RAN**



# 4G VERSUS 5G ARCHITECTURE

**Evolved Packet Core (EPC) in 4G**

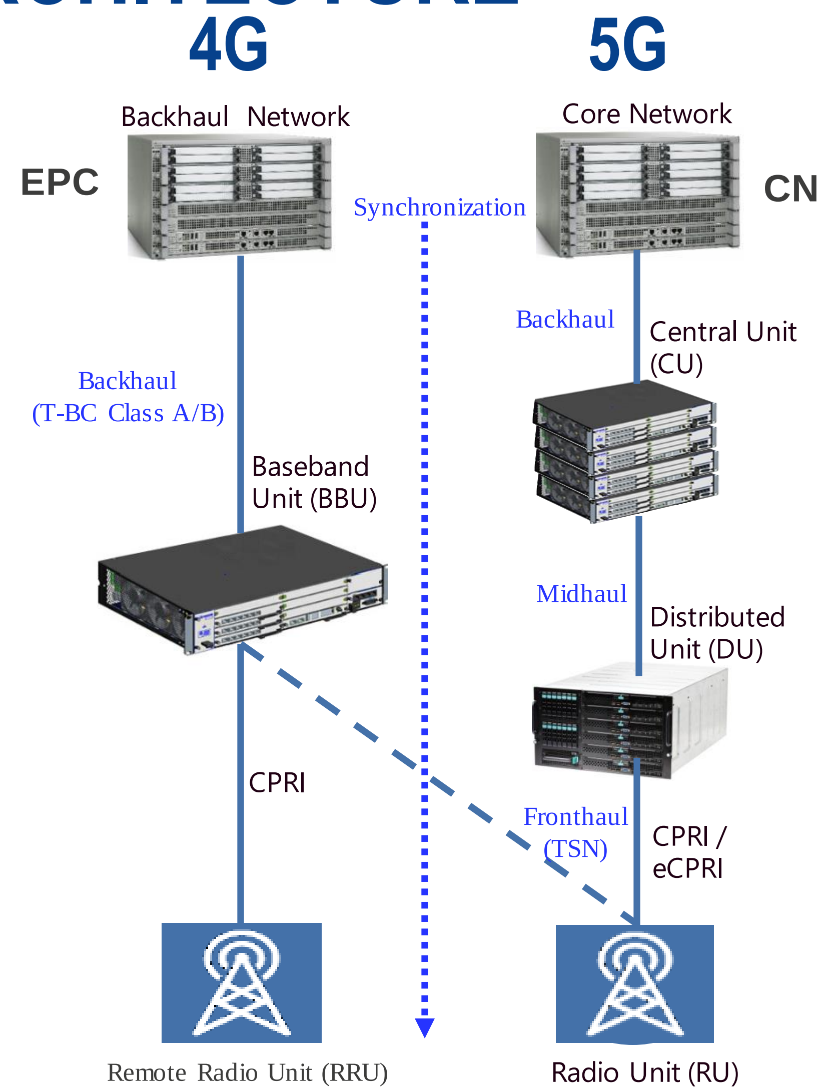
- Transport network implements Telecom Boundary clocks type A/B

**BBU in 4G :**

- BBU recovers sync from the network
- BBU implements IEEE 1588 and SyncE
- BBU implements Telecom Slave clock (T-TSC)

**RRU in 4G :**

- RRU recovers sync from CPRI signal alone
- Jitter performance is a key parameter for timing devices used in RRU




**Core Network (CN) in 5G**

- Transport network implements Telecom Boundary clocks type C/D

**BBU in 5G :**

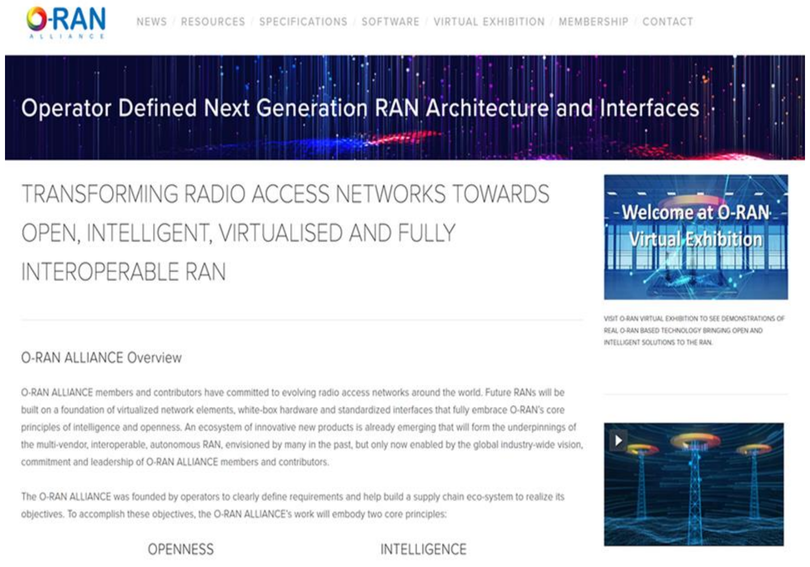
- BBU is split in 2 nodes (CU and DU)
  - CU (optionally) and DU both implement IEEE 1588 and SyncE
  - CU (optionally) and DU both implement Telecom Boundary clock (T-BC)
  - DU needs to implement clock classes C or D depending on the Operator

**RRU in 5G :**

- RRU cannot recover sync from eCPRI signal alone
  - RU needs to implement IEEE 1588 and SyncE (IEEE 802.1CM TSN)
- Jitter performance is a key parameter for timing devices used in RRU

# What is O-RAN ?

- **O-RAN (Open Radio Access Network)**
  - Operator Led Alliance
  - Initially formed in 2018
    [ORAN Forum + CRAN (China Mobile initiative)]
- **Use Standard Interfaces, Standard off-the-shelf Components, Standard functional splits, etc.**
  - Maximize common-off-the-shelf Hardware, Merchant Silicon
  - Minimize Proprietary Hardware
  - ***Use of GPP's + SW …***
- **Standardized Open Software and API**
  - Specified API and Interface
  - Adoption through Standardization
  - Explore Open source where appropriate
- **Driven for "open"ness**
  - The interfaces are standardized
  - Operators can mix/match different component vendors for the CUs, DUs, or RUs.
  - The components are interoperable, protocols are clearly defined



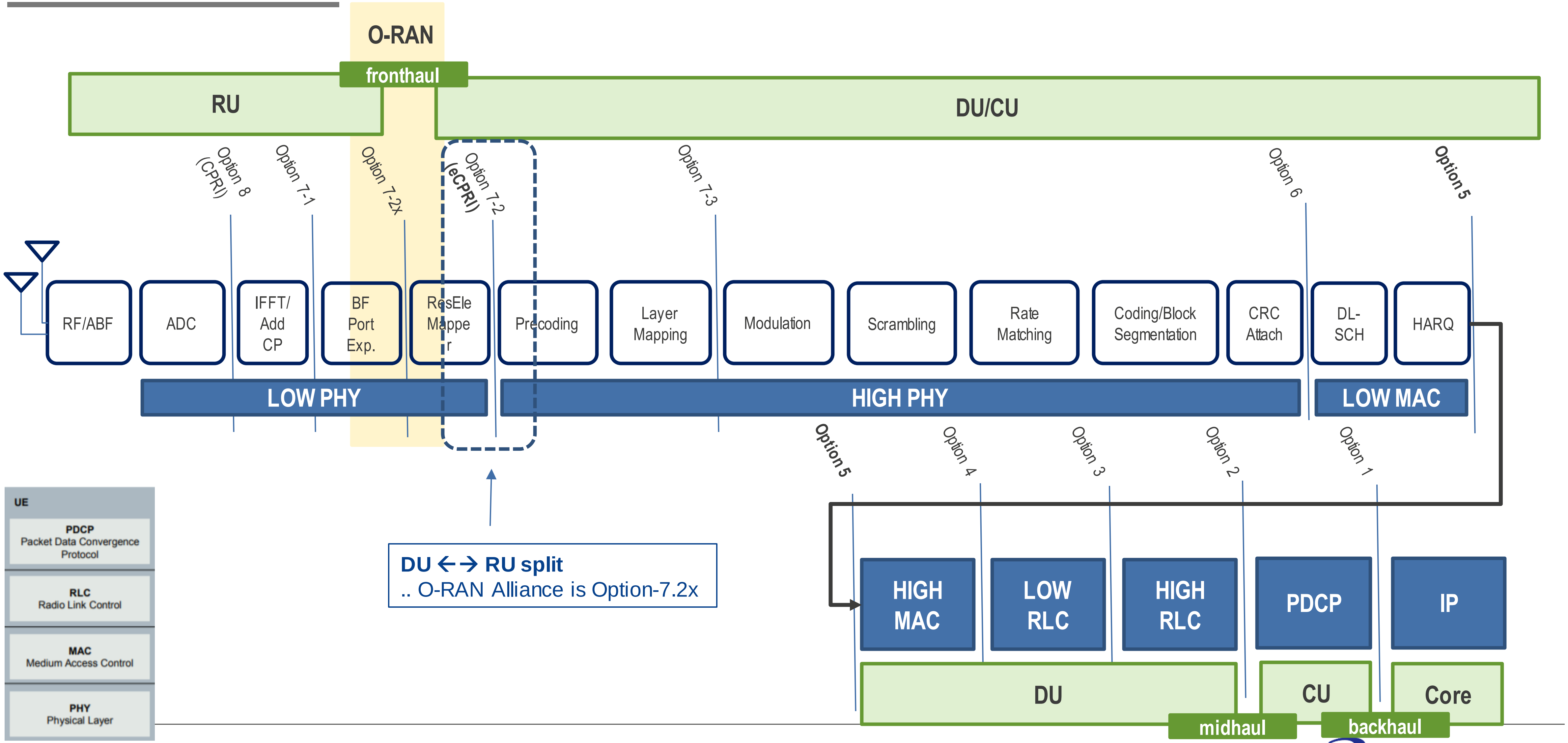

*ORAN Alliance following 3GPP and IMT-2020 for Open Network Architecture*

"Mission is to re-shape the RAN industry towards more intelligent, open, virtualized and fully interoperable mobile networks."

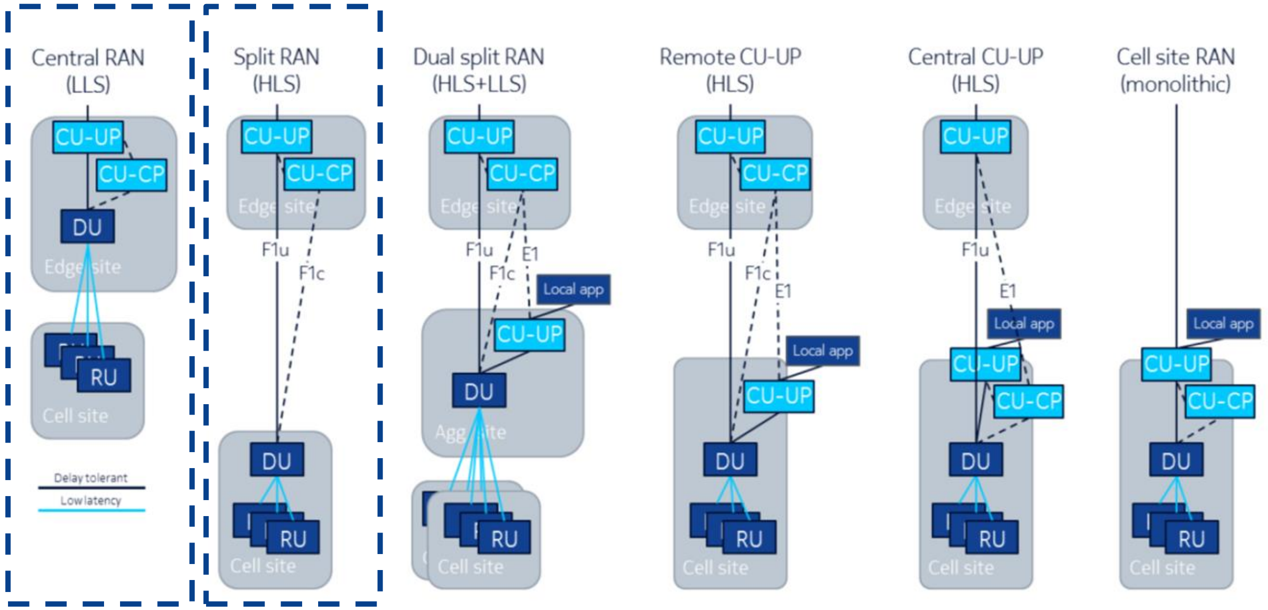
# O-RAN OVERVIEW

## ARCHITECTURE & FUNCTIONAL SPLITS

# FUNCTIONAL SPLITS – O-RAN SPECIFIC

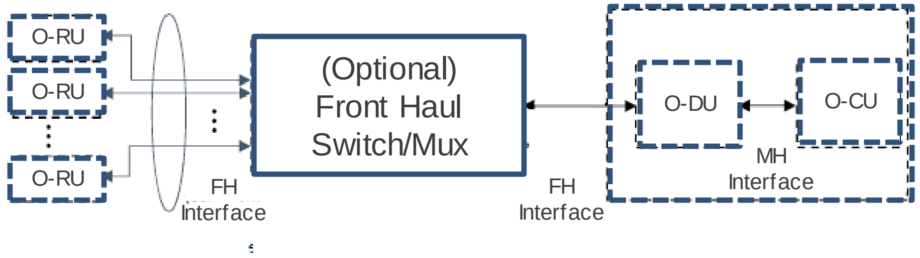


# VARIOUS DEPLOYMENT EXAMPLES*

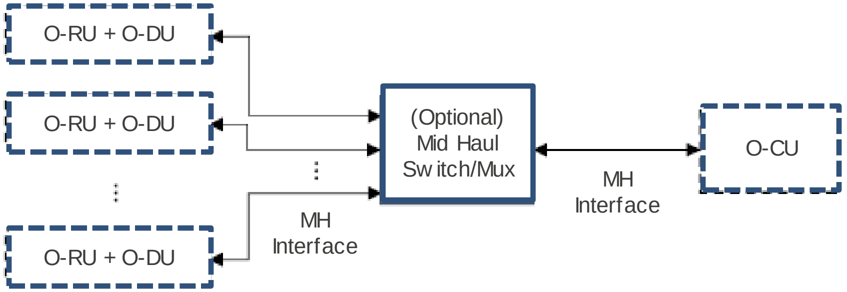



Scenario B – Initial Priority Focus

*The CU server/software co-located with the DU*
*… or hosted in a regional cloud data center.*




Central RAN, with Fronthaul Switch



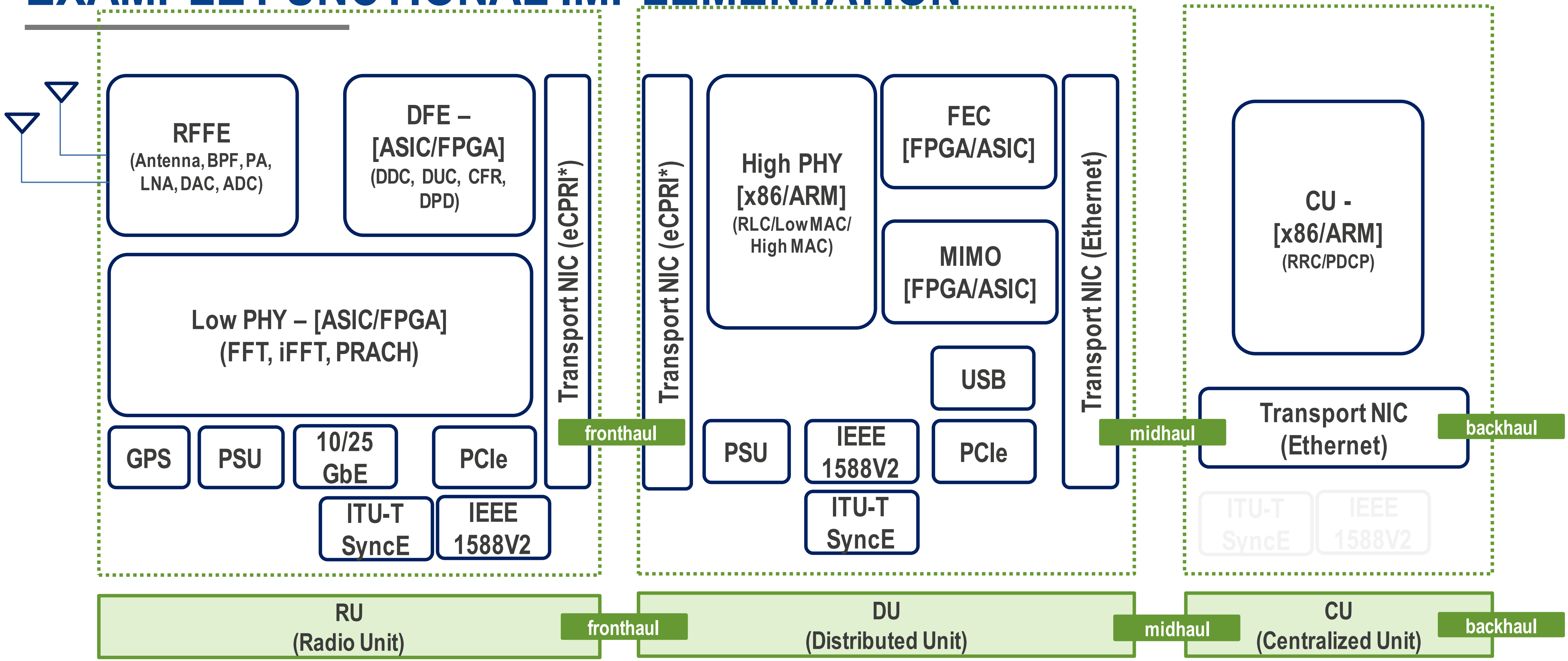

Split RAN, with Midhaul Switch

**Closer to Traditional 5G - Source: NGMN-2018*



BIG IDEAS FOR EVERY SPACE

# EXAMPLE FUNCTIONAL IMPLEMENTATION




*Source: Example based on TIP OpenRAN 5G NR BS Platform Requirements*
** eCPRI/RoE as well as CPRI support will be needed for coexistence/transition*

# TIME ACCURACY IN eCPRI

## SPECIFICATIONS

# 5G DRIVES TIGHTER SYNCHRONIZATION REQUIREMENTS

The 3GPP time alignment error (TAE) (or relative time error ($TE_R$), as used in ITU-T terminology) represents the largest timing difference measured between any two elements of the cluster

- Both 4G and 5G targets are 3 µs (±1.5 µs to common reference, or PRTC)
- TAE down to 130 ns between clusters of RUs (i.e. ±65 ns from same DU)

O-RAN CUS–plane spec also defines two classes of O-DU:

- Class A has ±15 ppb frequency error limit
- Class B has ±5 ppb limit

| Class level of accuracy | Maximum relative time error requirements (Note 1) | Typical applications (for information) |
|---|---|---|
| 3A | 5 µs | LTE MBSFN. |
| 4A | 3 µs | NR intra-band non-contiguous (FR1 only) and inter-band carrier aggregation; with or without MIMO or TX diversity. |
| 6A | 260 ns | LTE intra-band non-contiguous carrier aggregation with or without MIMO or TX diversity, and inter-band carrier aggregation with or without MIMO or TX diversity.<br>NR intra-band contiguous (FR1 only) and Intra-band non-contiguous (FR2 only) carrier aggregation, with or without MIMO or TX diversity. |
| 6B | 130 ns | LTE intra-band contiguous carrier aggregation, with or without MIMO or TX diversity.<br>NR (FR2) intra-band contiguous carrier aggregation, with or without MIMO or TX diversity. |
| 6C (Note 2) | 65 ns | LTE and NR MIMO or TX diversity transmissions, at each carrier frequency. |

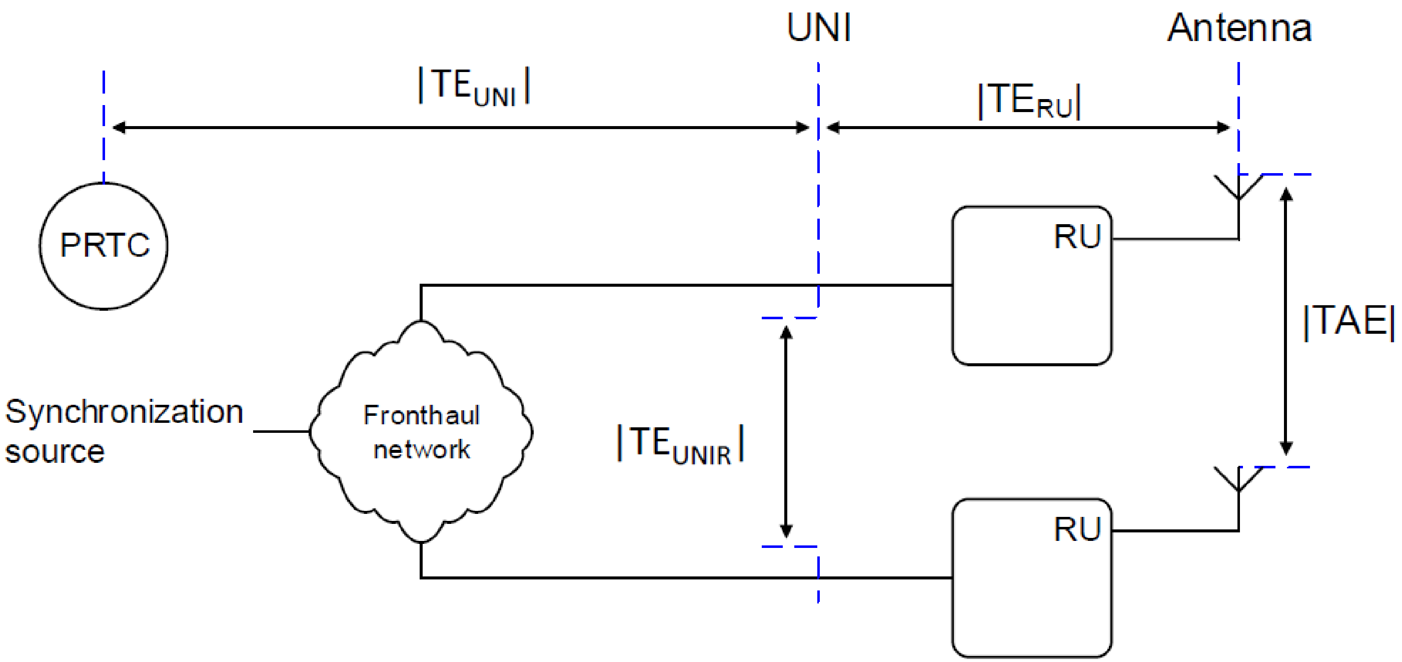
NOTE 1 – The maximum relative time error requirements represent the largest timing difference measured between any two elements of the cluster. See Appendix VII of [b-ITU-T G.8271.1] for illustration of how requirements are specified in a cluster. In 3GPP terminology this is equivalent to time alignment error (TAE).

NOTE 2 – Level 6C is an internal equipment specification, and does not result in a synchronization requirement on the transport network.

*ITU-T G.8271 Table 2 - Time and phase requirements for cluster based synchronisation*

# Time Error Budgets

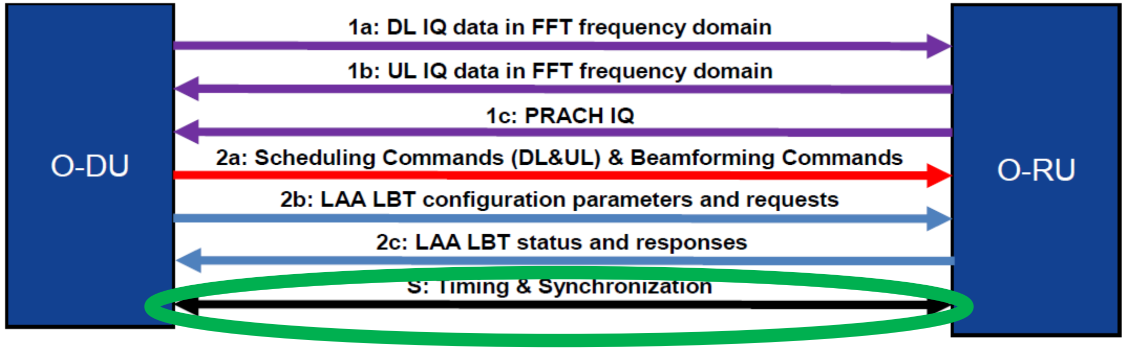
- **The eCPRI specification sets time error (TE) budgets for the usr network interface (UNIT)**
  - Allow for the time alignment error (TAE) requirements for four (4) categories of 3GPP features and RANs are met
  - Will focus on eCPRI timing accuracy categories A, B and C, and time synchronization deployment Cases 1.1 and 1.2
    - because these are most relevant to Open RAN applications
- **Reference Points and Definitions for eCPRI Fronthaul Networks**
  - The synchronization source could be a PRTC+T-GM, or DU that is directly or remotely synchronized by a PRTC.



# O-RAN OVERVIEW

## SYNCHRONIZATION PLANE

# O-RAN S-PLANE




- Timing and Synchronization Plane
  - Using SyncE SSM & IEEE 1588 PTP packets
  - Relative time error between the O-DU and O-RU should be within a limit of 3μs (±1.5 μsec)
- Current Version on O-RAN specification assumes transport of PTP directly over L2 Ethernet (ITU-T G.8275.1 full timing on-path support)
  - transport of PTP over UDP/IP (ITU-T G.8275.2 partial timing support from the network) is also possible

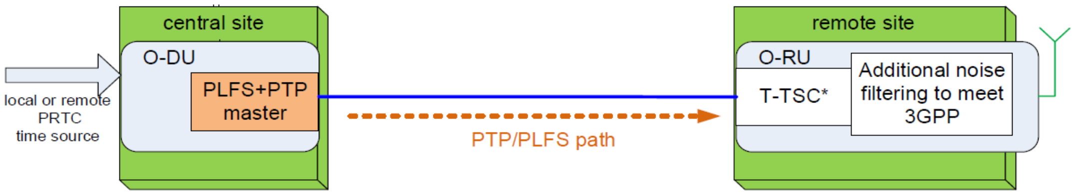
Four (4) O-RAN synchronization topologies:

- **Configuration LLS-C1**: the O-DU is part of the synchronization chain towards the O-RU. Network timing is distributed from O-DU to O-RU via direct connection between O-DU site and O-RU site.
- **Configuration LLS-C2**: the O-DU is part of the synchronization chain towards the O-RU. Network timing is distributed from O-DU to O-RU between O-DU sites and O-RU sites. One or more Ethernet switches are allowed in the fronthaul network.
- **Configuration LLS-C3**: the O-DU is not part of the synchronization chain towards the O-RU. Network timing is distributed from PRTC/T-GM to O-RU typically between central sites (or aggregation sites) and O-RU sites. One or more Ethernet switches are allowed in the fronthaul network.
- **Configuration LLS-C4**: the synchronization reference is provided to the O-RU with no involvement of the transport network (typically with a local GNSS receiver).

**How O-DU is synchronized is not in the scope of this classification of the synchronization topologies – but it cannot be ignored!!!**

# TOPOLOGIES

## LLS-C1




## LLS-C2

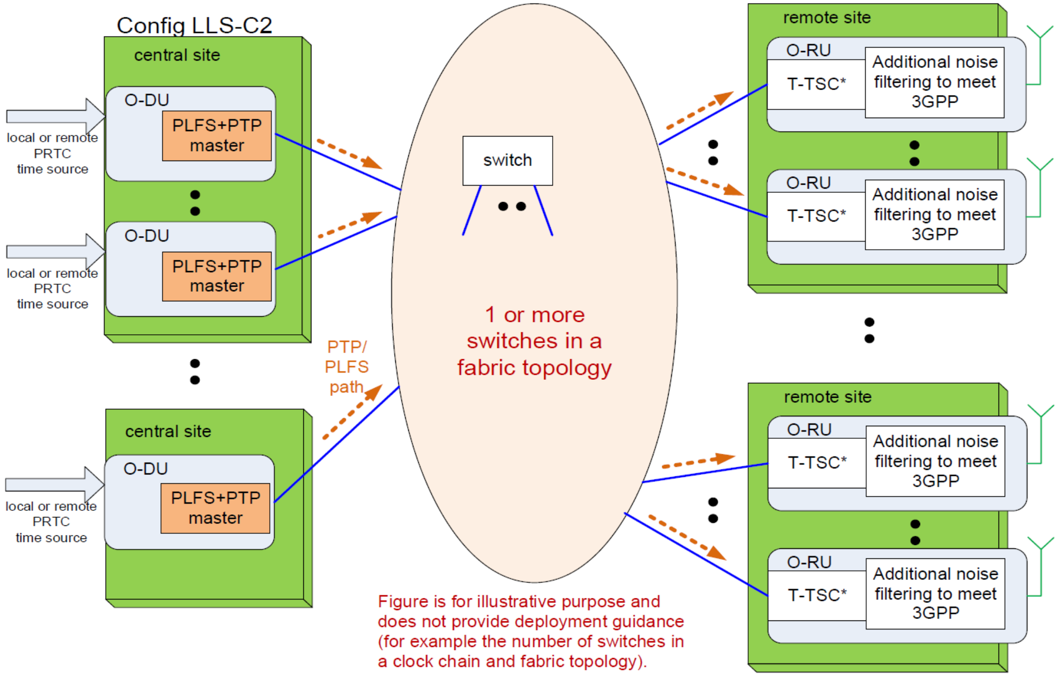



Figure is for illustrative purpose and does not provide deployment guidance (for example the number of switches in a clock chain and fabric topology).

## LLS-C3

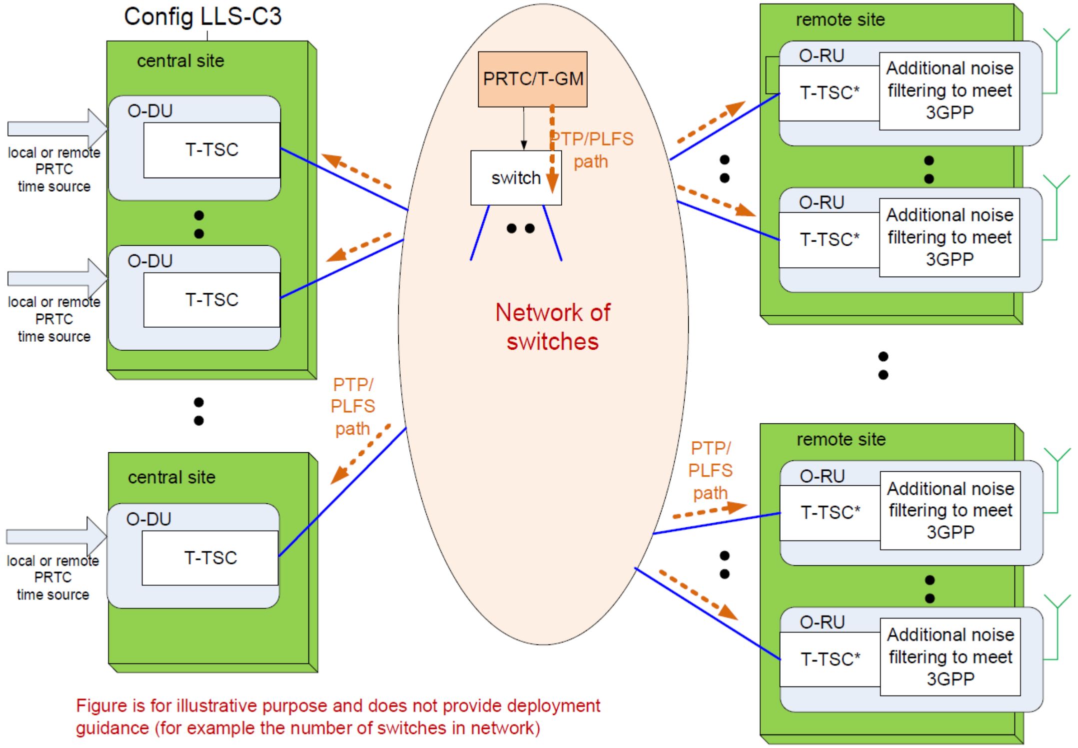
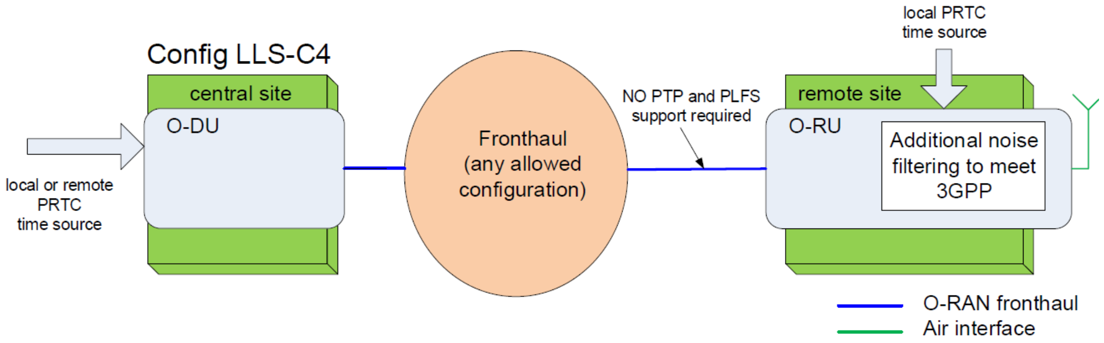



Figure is for illustrative purpose and does not provide deployment guidance (for example the number of switches in network)

## LLS-C4





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# O-RAN SYNCHRONIZATION FOR O-DU

| Configuration | Source | PLFS Master Toward Fronthaul | PTP Master Toward Fronthaul | Notes |
|---|---|---|---|---|
| LLS-C1 | Local/Remote PRTC or PTP from Backhaul | Yes | Yes | Point to point path |
| LLS-C2 | Local/Remote PRTC or PTP from Backhaul | Yes | Yes | Via 1 or more switches from O-DU to O-RU |
| LLS-C3 | PTP/SyncE from Fronthaul | No | No | Via 1 or more switches from T-GM in network<br>Uses ITU PTS (with SyncE) use case |
| LLS-C4 | Local/Remote PRTC | No | No | No timing output from O-DU. |

ORAN Terminology:
O-DU – open Distribution Unit, O-RU – open Radio Unit
Fronthaul – The network between the O-DU and O-RU
Backhaul – The network connecting the O-DU to the core network
PLFS (Physical Layer Frequency Signals) – same as ITU-T SyncE
Defined in **O-RAN.WG4.CUS.0-v06.00** with performance requirements in Table 9-3, 9-4 and 9-5

SyncE DPLL is recommended for O-DU systems to cover all synchronization topologies.

# O-RAN SYNCHRONIZATION FOR O-RU

| Configuration | PLFS Input? | PTP Input? | Fronthaul Network Type | Notes |
|---|---|---|---|---|
| LLS-C1 | Yes | Yes | FTS (with SyncE) | Point to point path |
| LLS-C2 | Yes | Yes | FTS (with SyncE) or PTS | Via 1 or more aware switches |
| LLS-C3 | Yes | Yes | FTS (with SyncE) or PTS | Via 1 or more switches from T-GM in network |
| LLS-C4 | No | No | N/A | No timing input from RU from network |

ORAN Terminology:
O-DU – open Distribution Unit, O-RU – open Radio Unit
Fronthaul – The network between the O-DU and O-RU
Backhaul – The network connecting the O-DU to the core network
PLFS (Physical Layer Frequency Signals) – same as ITU-T SyncE
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SyncE DPLL is recommended for O-DU systems to cover all synchronization topologies.

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# Timing is the heartbeat of the system