

# VIRTUAL TUTORIAL

## O-RAN FUNDAMENTALS SYNCHRONIZATION OVERVIEW

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# WORKSHOP ON SYNCHRONIZATION AND TIMING SYSTEMS

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# OUTLINE

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

# WHAT IS O-RAN

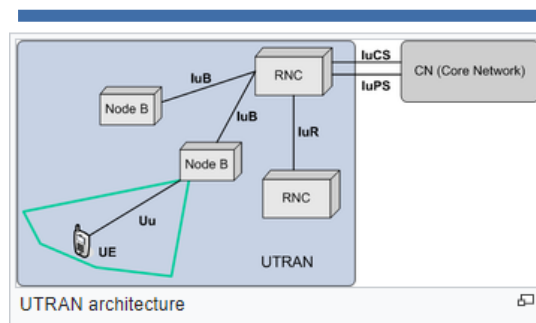
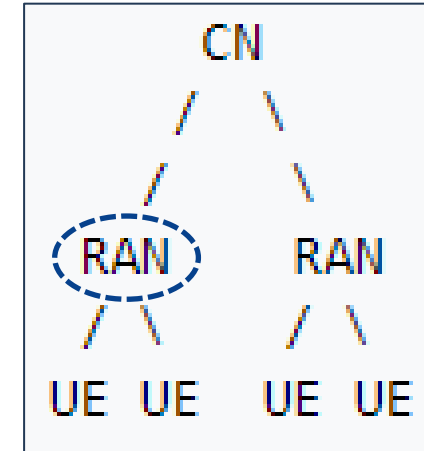
# First, What Is RAN ?

- **RAN = Radio Access Network**

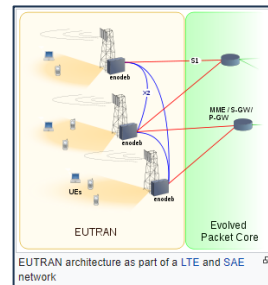
- It implements the radio access technology.
- Resides between the User Equipment (UE) and the Core Network (CN)

- **RAN history**

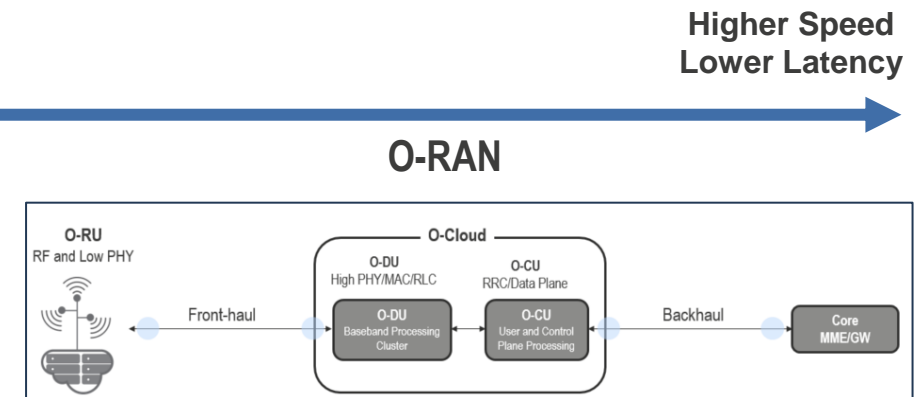
- GRAN GSM Radio Access Network → 2G
  - TDMA, CDMA
- UTRAN = UMTS Radio Access Network → 3G
  - W-CDMA radio access technology
- E-UTRAN = Evolved UMTS Radio Access Network → 4G
  - MIMO, OFDM, Long Term Evolution (LTE) → 4G LTE
- O-RAN = Open Radio Access Network → 5G
  - MIMO, mmWave, ESA (Beam Forming)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



UTRAN



E-UTRAN



# 4G VERSUS 5G ARCHITECTURE

## 4G

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

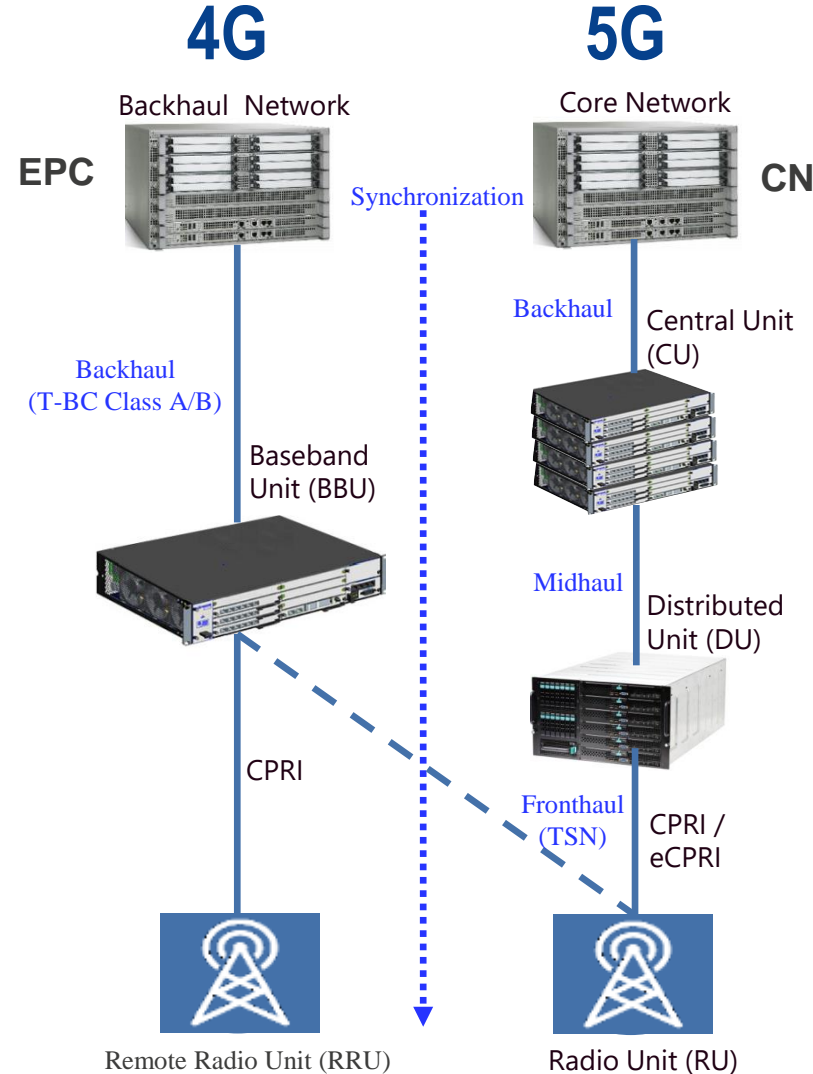
- Transport network implements Telecom Boundary clocks type A/B

### 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



## 5G

### 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.**

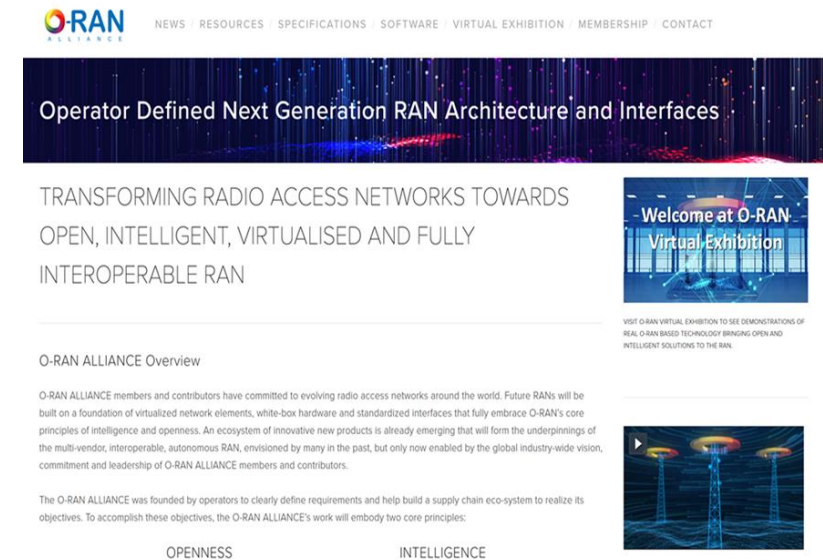
- Maximize common-off-the-shelf Hardware, Merchant Silicon
- Minimize Proprietary Hardware
- **Use of GPP's + SW ...**

- **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



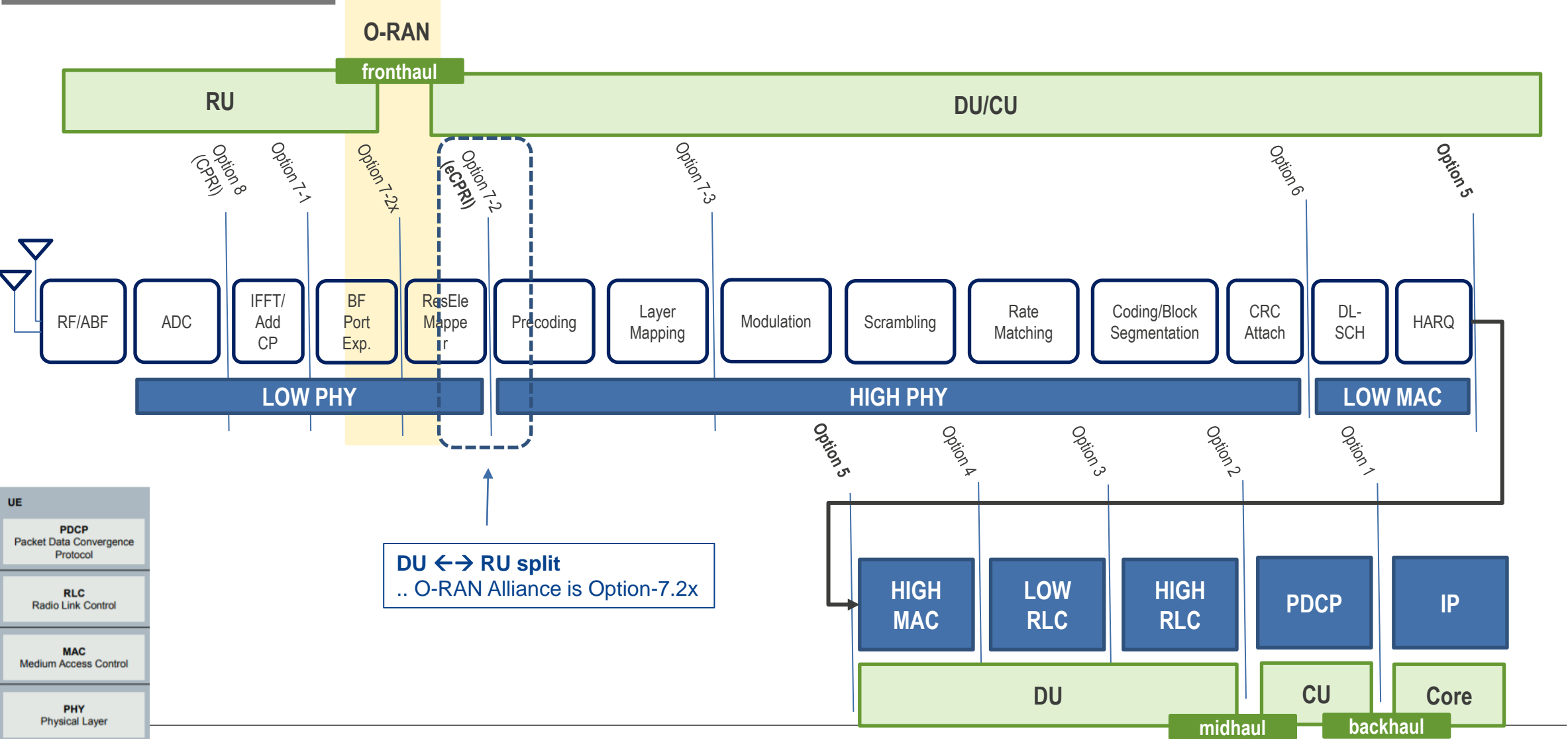
*ORAN Alliance following 3GPP and IMT-2020 for Open Network Architecture*

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

# O-RAN OVERVIEW

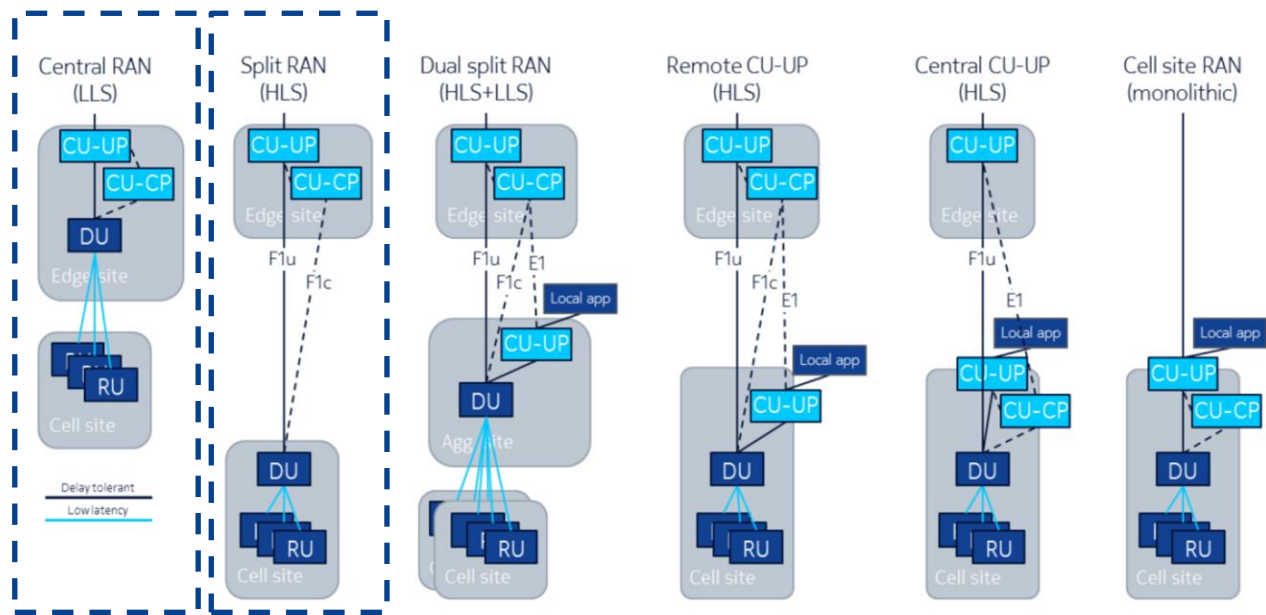
## ARCHITECTURE & FUNCTIONAL SPLITS

# FUNCTIONAL SPLITS – O-RAN SPECIFIC



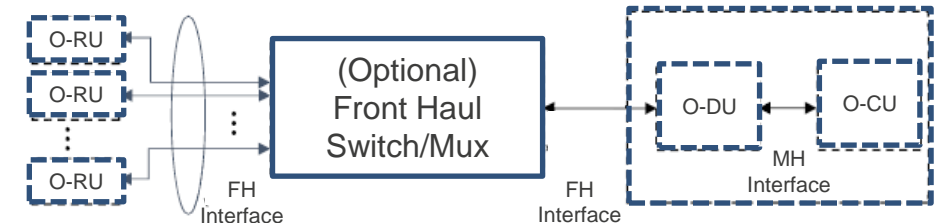


# VARIOUS DEPLOYMENT EXAMPLES\*

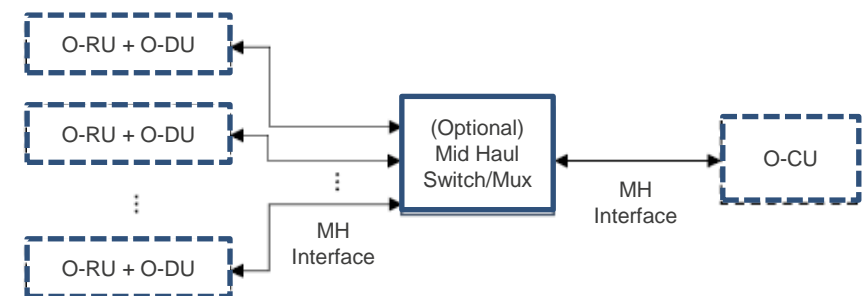


Scenario B – Initial Priority Focus

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



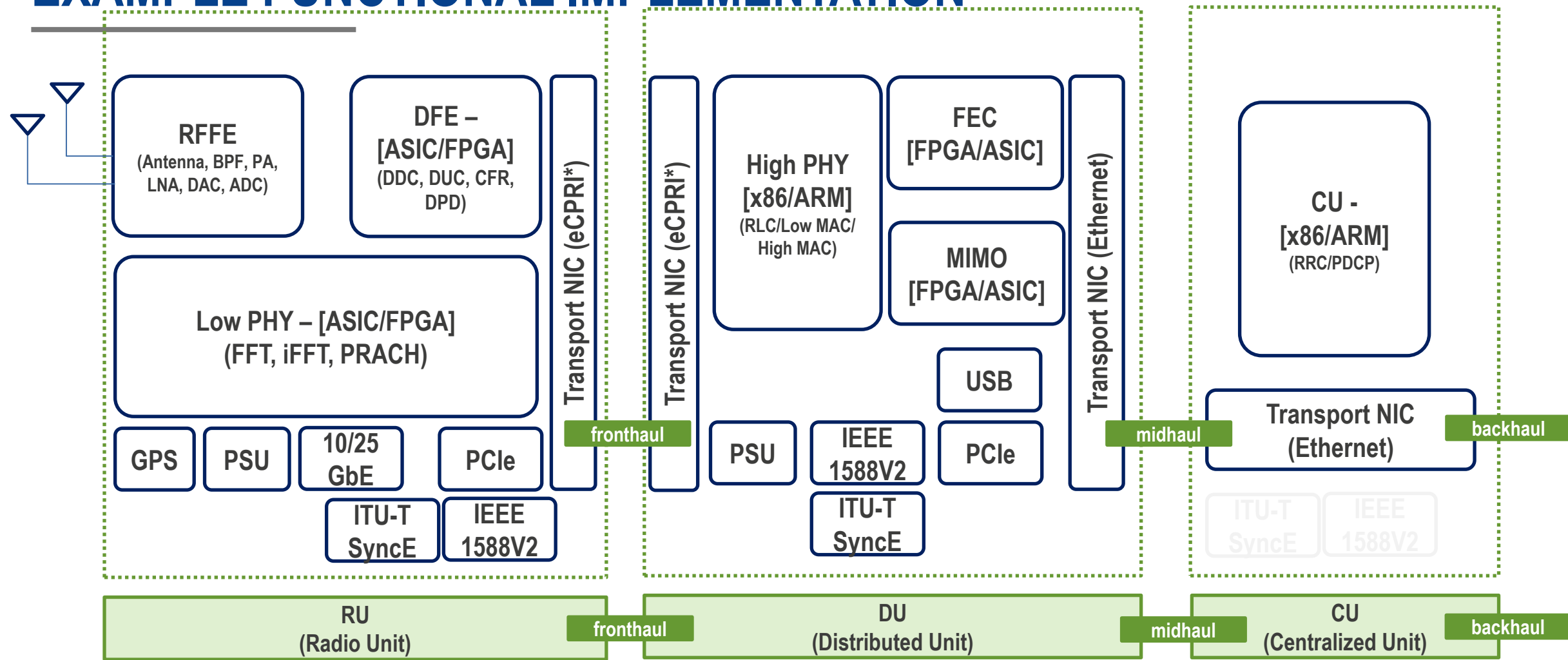
Central RAN, with Fronthaul Switch



Split RAN, with Midhaul Switch

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

# 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  $\mu$ s ( $\pm 1.5$   $\mu$ s to common reference, or PRTC)
- TAE down to 130 ns between clusters of RUs (i.e.  $\pm 65$  ns from same DU)

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

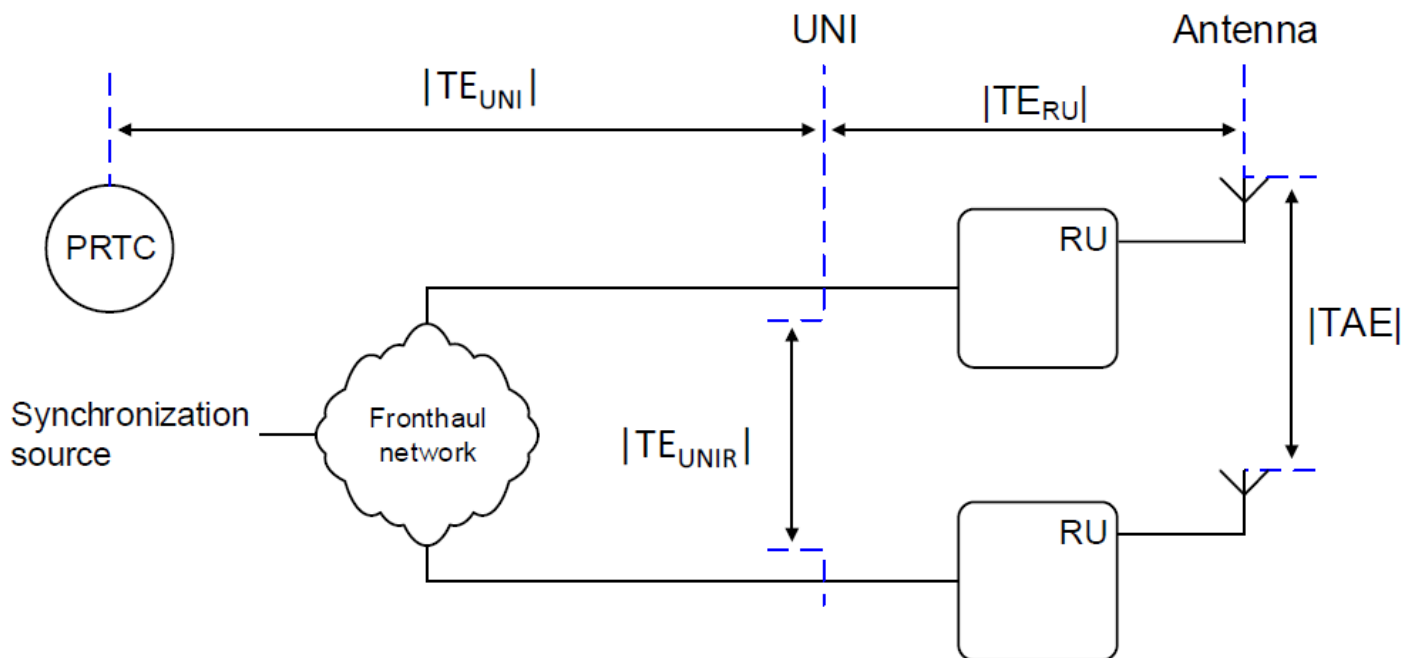
- Class A has  $\pm 15$  ppb frequency error limit
- Class B has  $\pm 5$  ppb limit

Class level of accuracy	Maximum relative time error requirements (Note 1)	Typical applications (for information)
3A	5 $\mu$ s	LTE MBSFN.
4A	3 $\mu$ s	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. 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. 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.
<p>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).</p> <p>NOTE 2 – Level 6C is an internal equipment specification, and does not result in a synchronization requirement on the transport network.</p>		

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

# Time Error Budgets

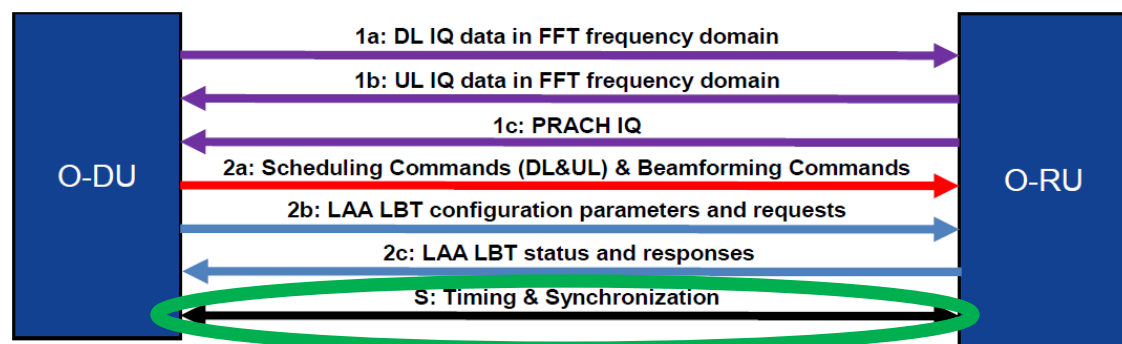
- **The eCPRI specification sets time error (TE) budgets for the user network interface (UNI)**
  - Allow for the time alignment error (TAE) requirements for four (4) categories of 3GPP features and RANs are met
  - Will focus on eCPRI timing accuracy categories A, B and C, and time synchronization deployment 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



Source: O-RAN.WG4.CUS

- 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  $3\mu\text{s}$  ( $\pm 1.5\mu\text{sec}$ )
- 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

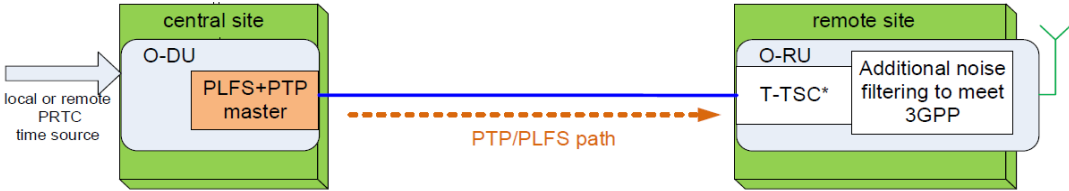
Four (4) O-RAN synchronization topologies:

- **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).

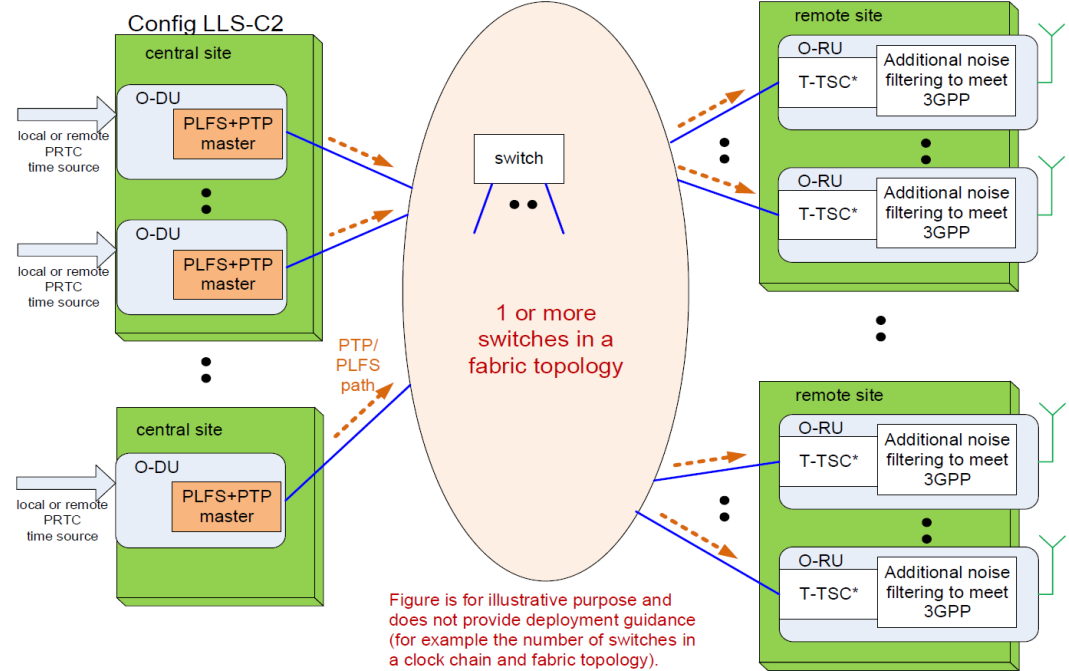
**How O-DU is synchronized is not in the scope of this classification of the synchronization topologies – but it cannot be ignored!!!**

# TOPOLOGIES

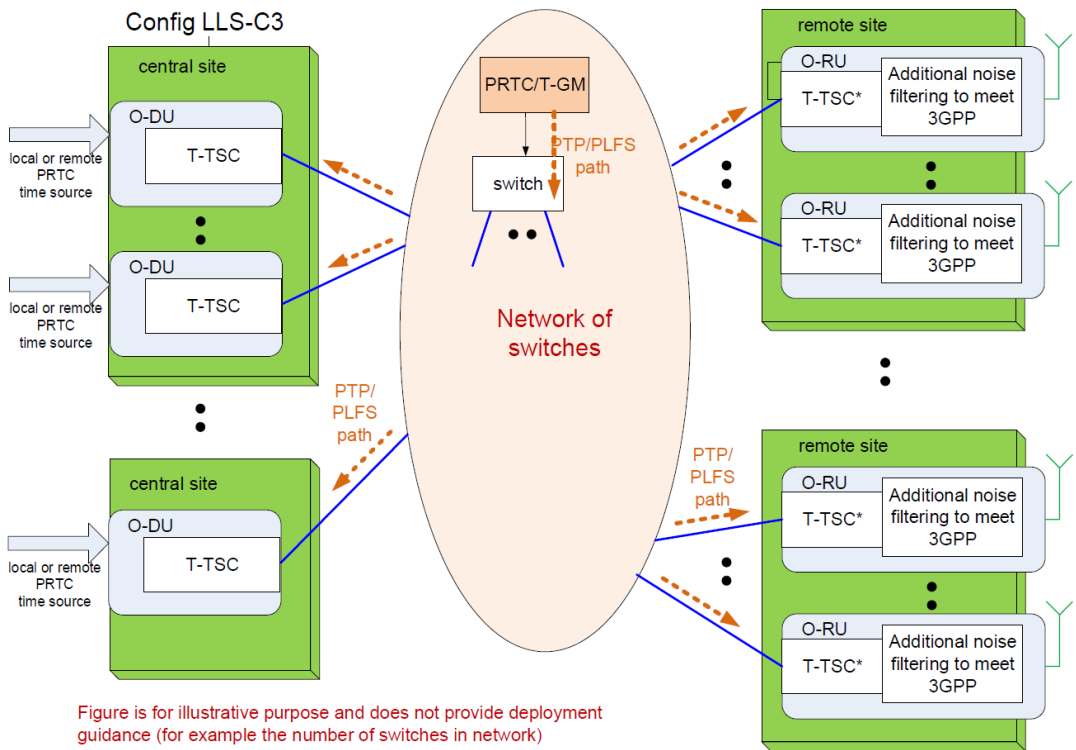
## LLS-C1



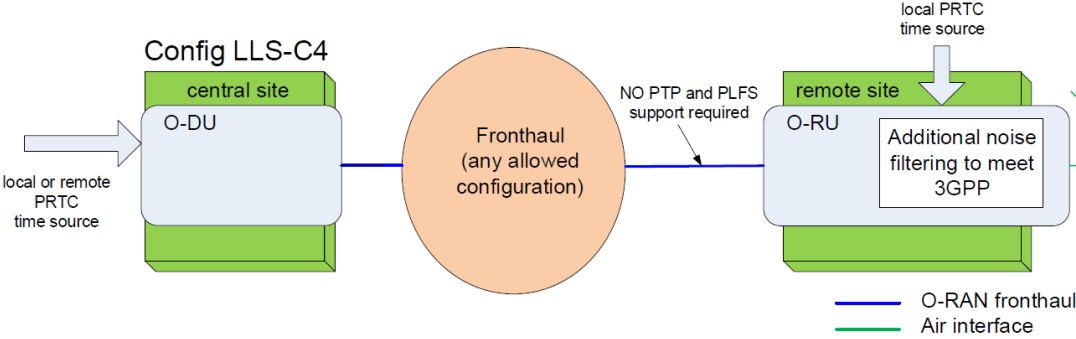
## LLS-C2



## LLS-C3



## LLS-C4





# 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 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

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O-DU – open Distribution Unit, O-RU – open Radio Unit

Fronthaul – The network between the O-DU and O-RU

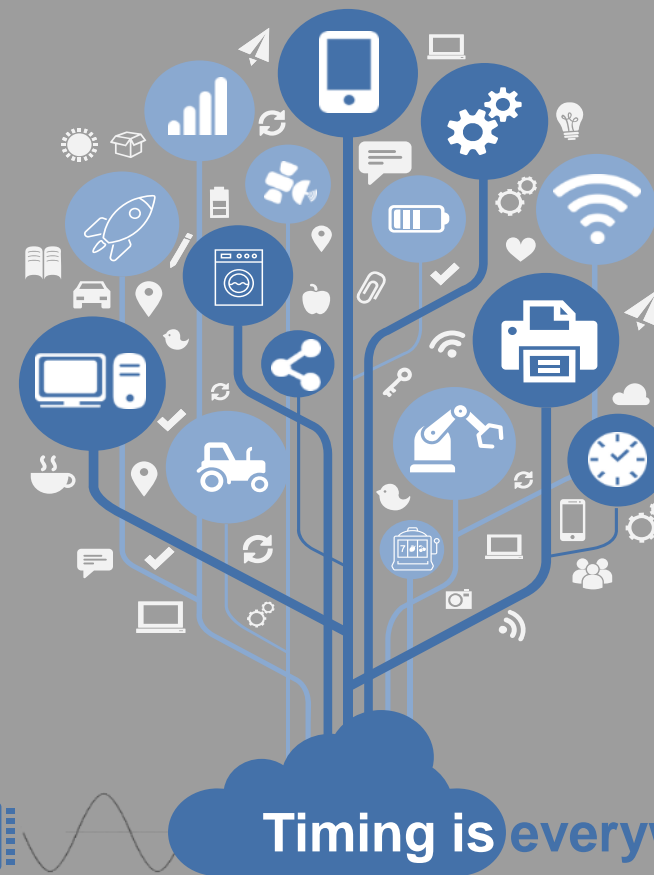
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SyncE DPLL is recommended for O-DU systems to cover all synchronization topologies.

# Timing is the heartbeat of the system



# Timing is everywhere