

**WORKSHOP**  
ON  
**SYNCHRONIZATION**  
AND  
**TIMING SYSTEMS**

MAY 9-12, 2022 | DENVER, CO

*THE EXPANDING  
SPECTRUM OF TIMING*

# 5G ORAN - TIMING AND SYNCHRONIZATION ARCHITECTURE AND SOLUTION

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**JUNIPER**  
NETWORKS

Engineering  
Simplicity

# AGENDA

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- **Overview of ORAN WG9 Work Group**
- **ORAN Sync Architecture and Solution spec**
- **Sync Requirements and Challenges**
- **Sync Architecture and Solution models**

# ORAN (OPEN RADIO ACCESS NETWORK) STANDARDS WORKGROUPS AND OBJECTIVES

Work Group	Objective
WG1	Use cases and Overall Architecture Workgroup
WG2	Non-real-time RIC and A1 Interface Workgroup
WG3	Near-Real-Time RIC and E2 Interface Workgroup
WG4	Open Fronthaul Interfaces Workgroup
WG5	Open F1/W1/E1/X2/Xn Interface Workgroup
WG6	Cloudification and Orchestration Workgroup
WG7	White-box Hardware Workgroup
WG8	Stack Reference Design Workgroup
WG9	Open X-haul Transport Workgroup
WG10	OAM for O-RAN

# ORAN WG9 – WORK ITEMS

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5G Transport Network Requirement

Ethernet/IP based Xhaul Transport Architecture

Xhaul Transport based on WDM

Xhaul Transport Management

Transport Network Timing and Sync

Transport Conformance and Testing

# ORAN WG9 – TIMING AND SYNC ARCHITECTURE AND SOLUTION SPEC



ORAN-WG9.XTRP-SYN.0-v02.00

Technical Specification

O-RAN Open X-haul Transport Working Group

Synchronization Architecture and Solution Specification



1	2	Contents	
2	1	Revision History.....	2
3	1.1	Contributors.....	2
4	3	Scope.....	5
5	4	References.....	6
6	5	Definitions and abbreviations.....	8
7	5.1	Definitions.....	8
8	5.2	Abbreviations.....	8
9	6	Network Timing and Synchronization Technology Overview.....	10
10	6.1	Building blocks of network-based synchronization.....	10
11	6.1.1	Synchronous Ethernet and Enhanced Synchronous Ethernet.....	10
12	6.1.2	PRC and clocks.....	11
13	6.1.3	PRTC and Grandmaster clocks.....	11
14	6.1.4	APTS.....	14
15	6.1.5	Boundary clocks, Ordinary clocks and Transparent clocks.....	15
16	6.2	Timing profiles.....	17
17	6.2.1	Full Timing Support (ITU-T G.8275.1).....	17
18	6.2.2	Partial Timing Support (ITU-T G.8275.2).....	18
19	6.2.3	Assisted Partial Timing Support (ITU-T G.8275.2).....	19
20	6.2.4	Profile comparison table with important attributes.....	20
21	6.2.5	Inter-working (IWF) function.....	21
22	6.2.6	A-BMCA algorithm and PTP attributes to consider.....	22
23	6.3	Synchronization time error budgeting model.....	23
24	6.3.1	Factors to be considered for network synchronization budgeting.....	23
25	6.3.2	Time Error budget calculation.....	28
26	6.3.3	Different ORAN config models with Time Error budget.....	32
27	7	Synchronization network models.....	39
28	7.1	Factors to be considered for synchronization network design.....	39
29	7.1.1	Source of clock and location of clock source.....	39
30	7.1.2	GM/clock source resiliency.....	39
31	7.1.3	Holdover requirements.....	39
32	7.1.4	Usage of packet rates.....	40
33	7.1.5	Network Topology model.....	41
34	7.1.6	Number of hops.....	44
35	7.1.7	Asymmetry.....	46
36	7.1.8	PTP packet transport.....	48
37	7.1.9	Selection of timing profile.....	49
38	7.2	GM deployment models.....	50
39	7.2.1	Centralized GM network model.....	50
40	7.2.2	Distributed GM network model.....	51
41	7.2.3	Fully distributed GM/PRTC network model.....	51
42	7.2.4	Comparison of Centralized versus Distributed GM network model.....	52
43	8	Timing Use cases and Solution Options.....	53
44	8.1	Transport network topology.....	53
45	8.1.1	C-RAN Architecture with non-collocated O-RU and O-DU.....	53
46	8.1.2	C-RAN Architecture with O-RU and O-DU collocated at cell site.....	55
47	8.2	Timing Solution Options.....	56
48	8.2.1	Timing Solutions for C-RAN Architecture with non-collocated O-RU and O-DU.....	56
49	8.2.2	Timing Solutions for C-RAN Architecture with O-RU and O-DU collocated at cell site.....	63
50	8.2.3	Timing/Synchronization Redundancy & Resiliency.....	65
51		Annex A Microwave and mmWave radio transport.....	82
52	A.1	Conformance to IEEE1588 and PTP profiles.....	82
53	A.2	Impact of Radio channel bandwidth.....	82

ORAN-WG9.XTRP-SYN.0-v02.00



1	A.3	Impact of interference.....	83
2	A.4	Impact of dynamic capacity variations.....	83
3	A.5	Impact of Band and Carrier Aggregation.....	83
4	A.6	Point to Multi Point (PMP) radio system.....	83
5	A.7	Radio Interface with asymmetry latency.....	84
6	A.8	Holdover Spec of BC function on the wireless transport node.....	84
7	A.9	Considering of characteristics in multiple hops.....	84
8		Annex B Radio operation when synchronization is lost.....	86
9	B.1	Potential impacts due to sync loss on O-RUs.....	86
10	B.1.1	TAE errors beyond the allowed range during sync loss.....	86
11	B.1.2	Impact on Handover/Handoff.....	86
12	B.2	Potential impacts due to sync loss on O-DU.....	87
13	B.2.1	O-DU Sync loss in LLS-C3 topology.....	87
14	B.2.2	O-DU Sync loss in LLS-C1/C2 topology.....	87
15	B.3	Best Practices.....	88
16		Annex C QoS Considerations for PTP packets.....	89
17		Annex D R-PHY (DOCSIS over Ethernet).....	94
18		Annex E Synchronization over TDM PON.....	95
19	E.1	Short introduction to TDM PON.....	95
20	E.2	Specifics with TDM PON (compared to point-point links) for frequency synchronization.....	97
21	E.3	Specifics with TDM PON (compared to point-point links) for time synchronization.....	97
22	E.3.1	Different use cases and related requirements.....	97
23	E.3.2	TDM PON capabilities.....	102
24	E.3.3	Overview of TDM PON support use cases.....	104
25		Annex F Multi-TDD operator considerations.....	105
26		Annex G Encryption and Authentication for PTP packets (MACsec and IPsec).....	106
27		Annex ZZZ: O-RAN Adopter License Agreement.....	107
28		Section 1: DEFINITIONS.....	107
29		Section 2: COPYRIGHT LICENSE.....	107
30		Section 3: FRAND LICENSE.....	108
31		Section 4: TERM AND TERMINATION.....	108
32		Section 5: CONFIDENTIALITY.....	108
33		Section 6: INDEMNIFICATION.....	109
34		Section 7: LIMITATIONS ON LIABILITY; NO WARRANTY.....	109
35		Section 8: ASSIGNMENT.....	109
36		Section 9: THIRD-PARTY BENEFICIARY RIGHTS.....	109
37		Section 10: BINDING ON AFFILIATES.....	109
38		Section 11: GENERAL.....	109
39			

# SYNC REQUIREMENTS

## TAE requirements at O-RU Air interface

LTE Features	TAE  relative or absolute	Corresponding Timing Category in 802.1CM/eCPRI standard (Informative)
TDD	Relative  TAE  $\leq 3\mu\text{s}$ (cell radius < 3km) Relative  TAE  $\leq 10\mu\text{s}$ (cell radius > 3km) (note 1) TS36.133	Timing Category C
Dual connectivity	Relative  TAE  $\leq 3\mu\text{s}$ (note 1) TS36.133	Timing Category C
MIMO or Tx Diversity	Relative  TAE  $\leq 65\text{ns}$ (note 2, note 4) TS36.104	
CA (intra-band contiguous)	Relative  TAE  $\leq 130\text{ns}$ (note 2, note 5) TS36.104	Timing Category A (note 3)
CA (interband or intra-band non-contiguous)	Relative  TAE  $\leq 260\text{ns}$ (note 2) TS36.104	Timing Category B (note 3)
OTDOA	Absolute  TAE  at O-RU antenna $\ll 1.5\mu\text{s}$ , $\sim 100\text{-}200\text{ ns}$ (not defined by 3GPP)	Not covered since it is not defined by 3GPP

## O-RU Air interface frequency error

The O-RAN fronthaul network shall ensure O-RU meeting a **+/-50ppb** air interface frequency error requirement. 3GPP TS 36.104 (for LTE macro cells) and TS 38.104 (for 5G macro) specify +/-50ppb as the short-term average error in 1ms duration applicable to both LTE and 5G technologies.

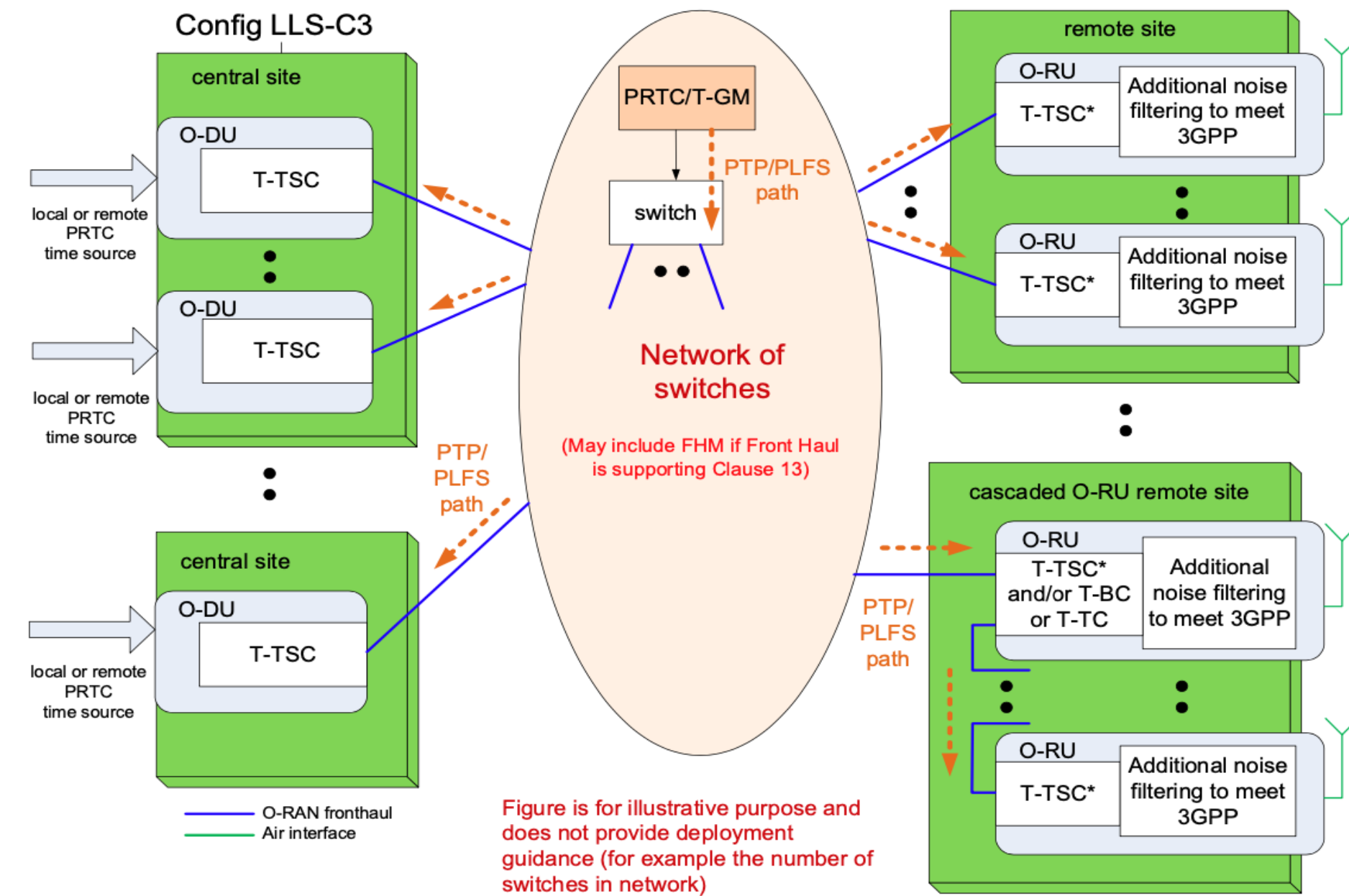
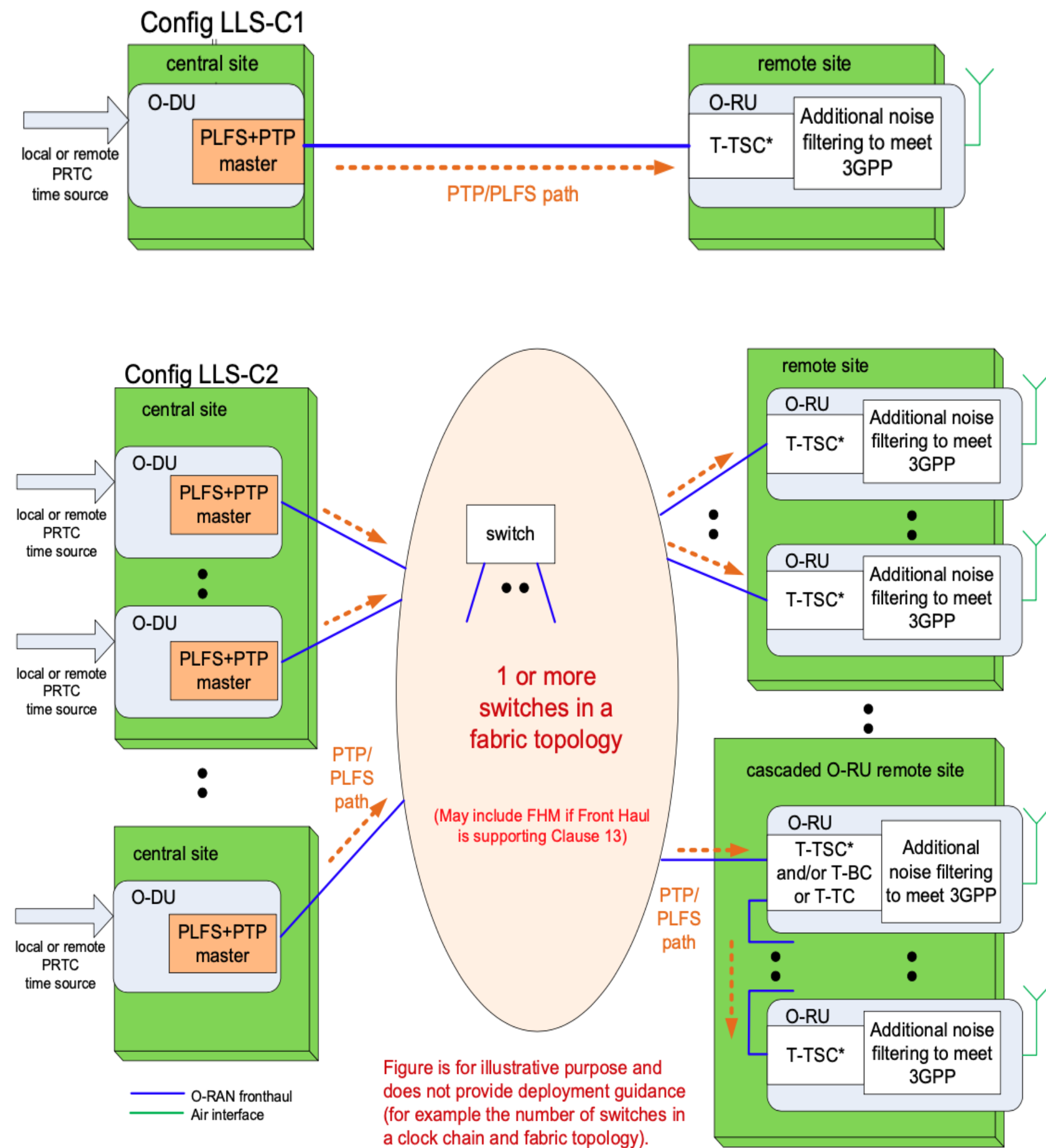
Source: O-RAN-WG4.CUS.0-v08.00 specification

# SYNC CHALLENGES

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- **Stringent TAE requirements**
- **Resiliency**
- **Holdover**
- **Security**

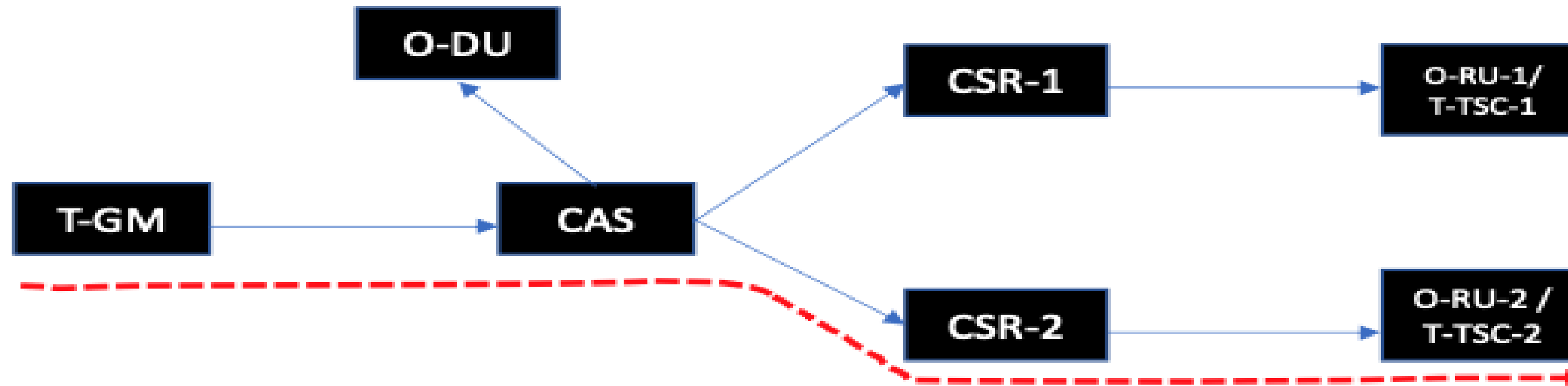
# ORAN CONFIG MODELS



Source: O-RAN-WG4.CUS.0-v08.00 specification



# CASE-1: T-GM TO RADIO INTERFACE (O-RU)



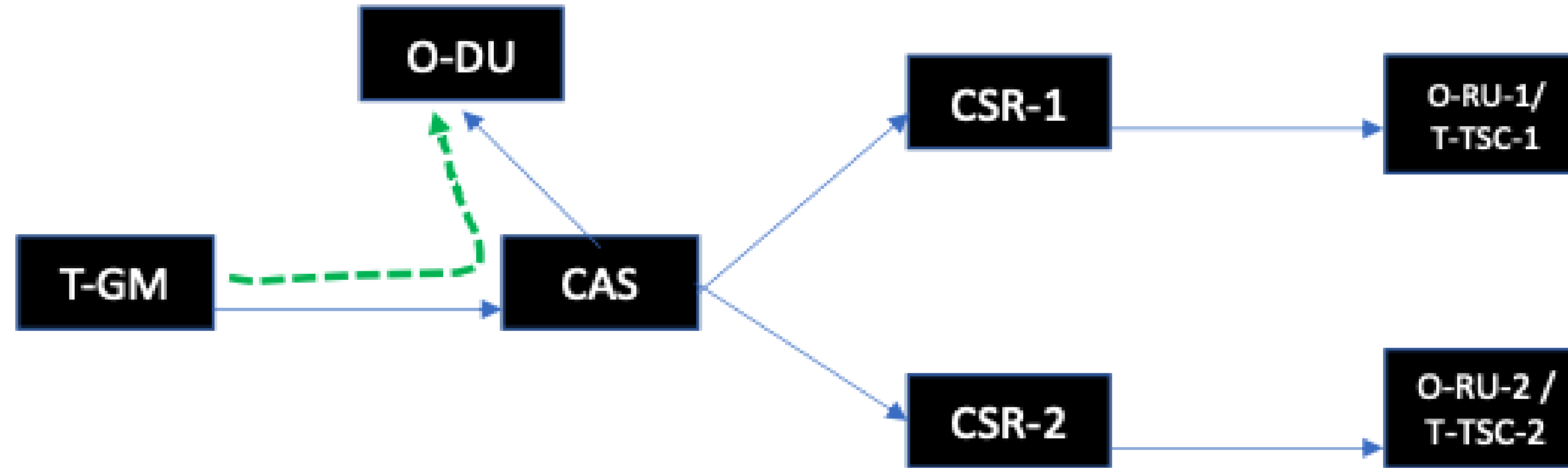
$$\max |TE_N| \leq \sum_{i=1}^N |cTE_i| + \sum_{j=1}^{N-1} |linkTE_j| + \sqrt{\left\{ \sum_{i=1}^N \left[ \max |d^L TE_i(t)| \right]^2 \right\} + \left[ \max |d^H TE_N(t)| \right]^2}$$

$\max |TE|$  Maximum Absolute Time Error  
 $cTE$  constant Time Error  
 $dTE_L$  dynamic Time Error (low frequency)  
 $dTE_H$  dynamic Time Error (high frequency)  
 $linkTE$  Time Error introduced by link asymmetry

- Assumptions:
- T-GM is PRTC-B = +/- 40nsec
  - CAS, CSR are class-C devices ( $cTE = +/- 10$ ) and  $dTE_L = 10nsec$
  - O-RU-1 and O-RU-2 are enhanced RU with max TE of 35nsec

- $E2E \max |TE| = \max TE(T-GM) + cTE(CAS) + cTE(CSR) + \sqrt{\max |dTE(CAS)|^2 + \max |dTE(CSR)|^2} + \max TE(O-RU)$
- $E2E \max |TE| = 40 + 10 + 10 + \sqrt{10^2 + 10^2} + 35 \Rightarrow 109.14nsec \Rightarrow 109.14 nsec$

## CASE-2: T-GM TO O-DU

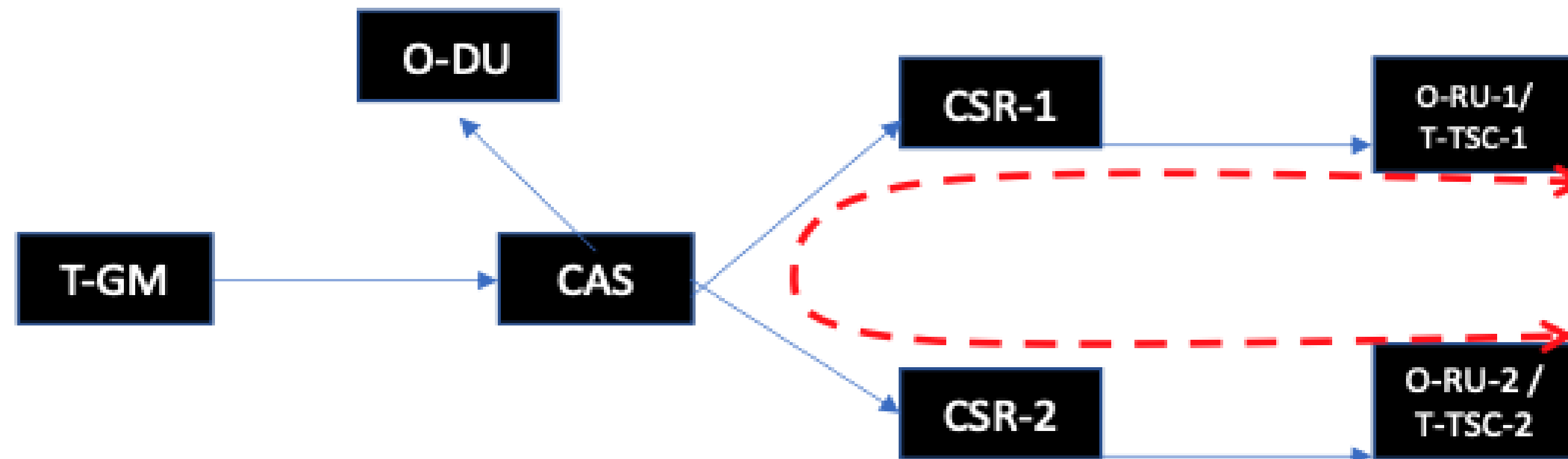


### Assumptions:

- T-GM is PRTC-B = +/- 40nsec
- CAS and CSR are class-C devices (cTE= +/-10) and  $dTE_L = 10nsec$
- RU-1 and RU-2 are enhanced RU with max TE of 35nsec
- DU is class-A device with cTE = +/-50 nsec

- $E2E \text{ Max } |TE| = \text{maxTE}(T-GM) + cTE(CAS) + cTE(O-DU) + \text{sqrt}(\text{max } |dTE_L(CAS)|^2)$
- $E2E \text{ max } |TE| = 40 + 10 + 50 + \text{sqrt}(10^2) \Rightarrow 110 \text{ nsec}$

## CASE-3: RADIO INTERFACE TO RADIO INTERFACE (TAE)



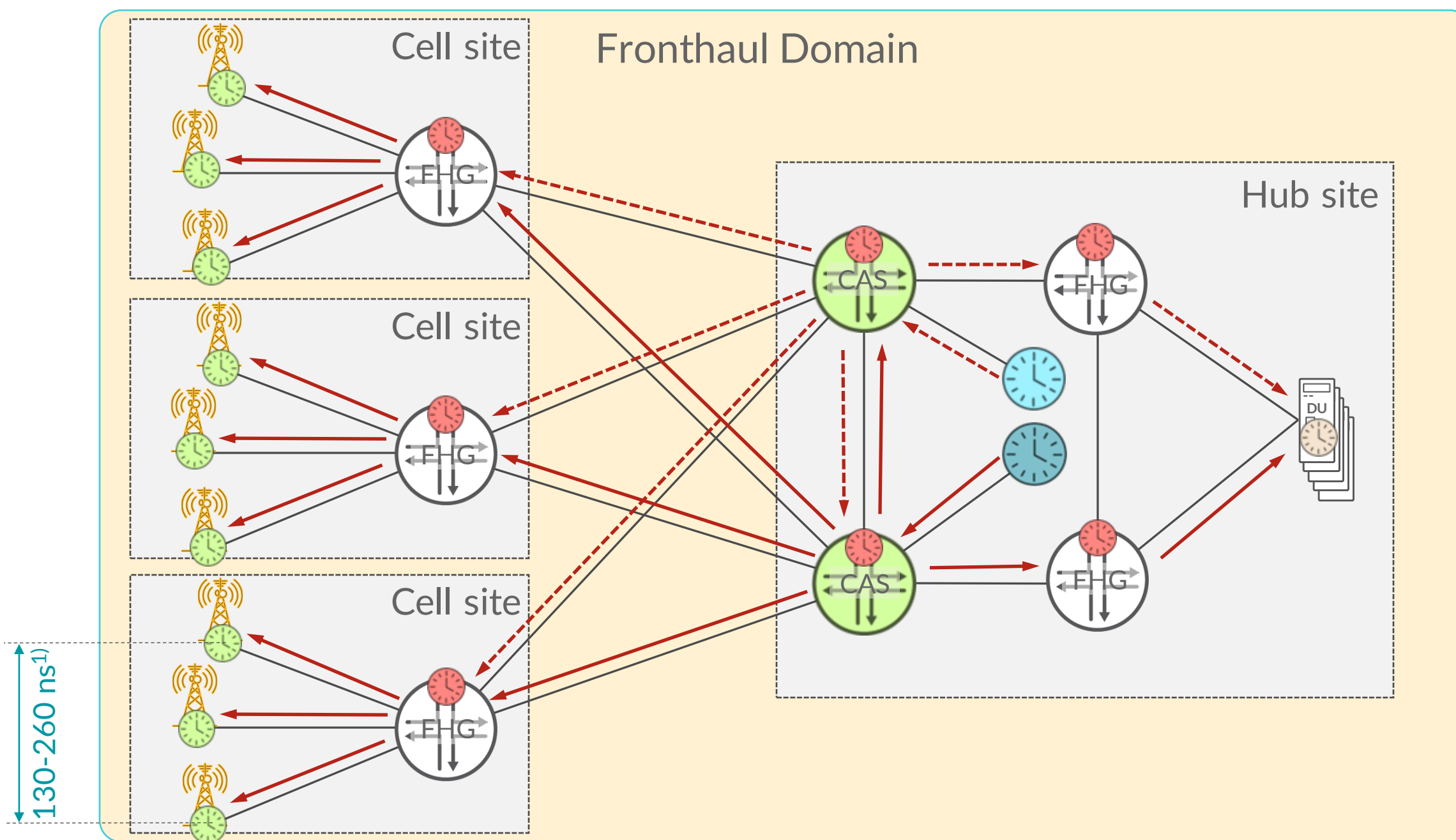
### Assumptions:







- T-GM is PRTC-B = +/- 40nsec
- CAS, CSR are class-C devices (cTE= +/-10) and  $dTE_L = 10\text{nsec}$
- O-RU-1 and O-RU-2 are enhanced RU with max TE of 35nsec
- $cTE_R = 12\text{ nsec}$  and  $dTE_{RL} = 14\text{ nsec}$

- Relative Max |TE| =  $\max\text{TE}(\text{O-RU1}) + \max\text{TE}(\text{O-RU2}) + c\text{TE}(\text{CSR1}) + c\text{TE}_R(\text{CAS}) + c\text{TE}(\text{CSR2}) + \sqrt{\max(d\text{TE}_{RL}(\text{CAS})^2 + d\text{TE}_L(\text{CSR1})^2 + d\text{TE}_L(\text{CSR2})^2)}$
- Relative max |TE| =  $35 + 35 + 10 + 12 + 10 + \sqrt{14^2 + 10^2 + 10^2} \Rightarrow 121.89\text{ nsec}$

# FRONTHAUL TIMING & SYNCHRONIZATION DESIGN

## TIME ALIGNMENT ERROR (TAE) BETWEEN TWO RUs CONNECTED TO SAME FHG



-  T-GM (Primary/Backup)  
(PRTC-B: |TE| ≤ 40ns)
-  T-BC Class C  
(|cTE| ≤ 10 ns, |dTE<sub>L</sub>| ≤ 10 ns  
cTE<sub>R</sub> ≤ 12 ns, dTE<sub>RL</sub> ≤ 14 ns)
-  T-TSC Class B  
(|cTE| ≤ 20 ns, |dTE<sub>L</sub>| ≤ 20 ns)
-  enhanced-RU (eRU)  
(|TE| ≤ 35 ns)
-  PTPoE + SyncE (G.8275.1)
- 

### Resiliency & Holdover:

- FHGs source time from multiple CAS
- CASs source time from two different T-GMs
- O-DUs source time from two different FHGs

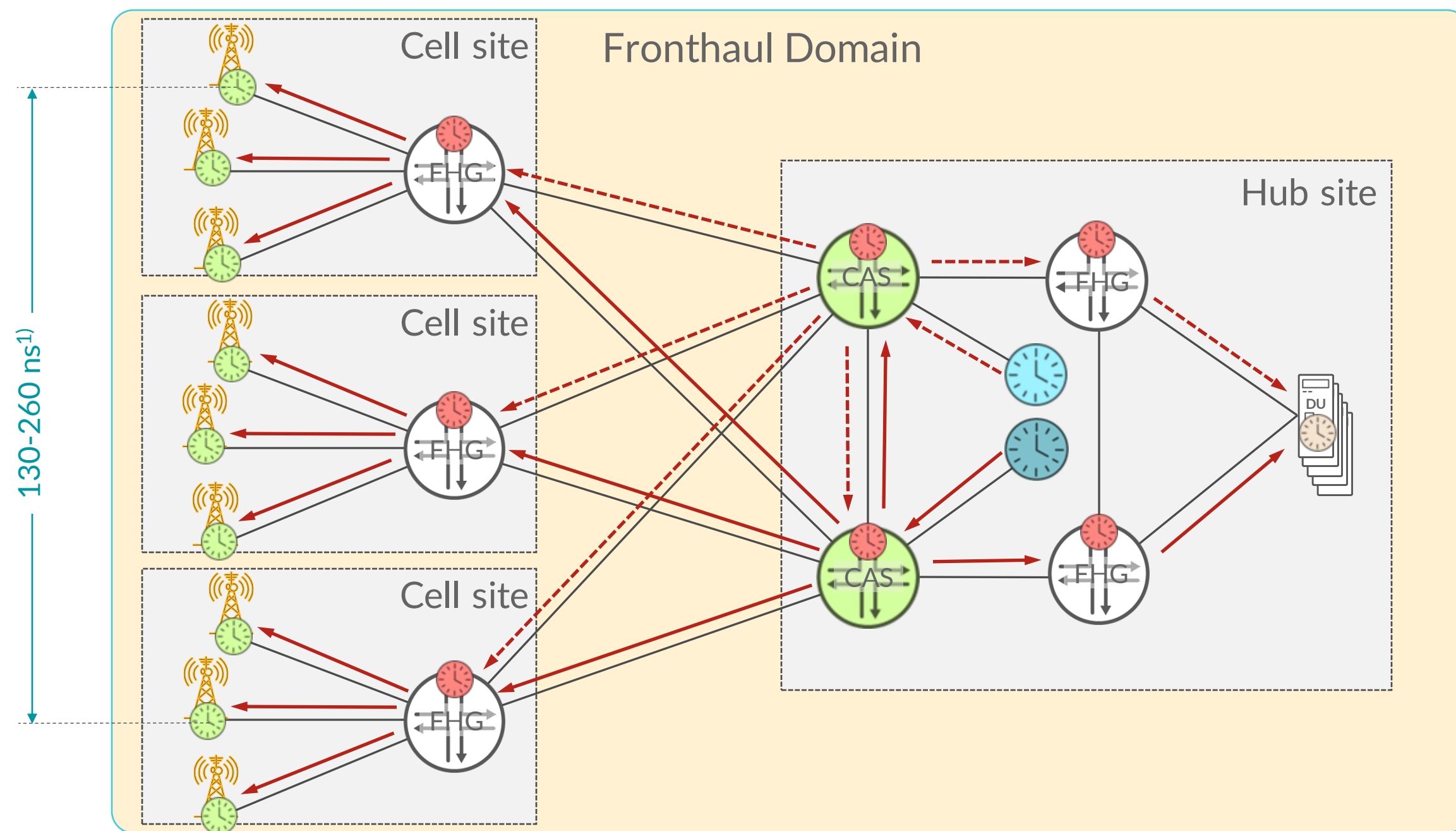
$$\max|TAE| \leq \max TE(RU_A) + \max TE(RU_B) + cTER(FHG) + \sqrt{\max |dTERL(FHG)|^2}$$

$$\max|TAE| \leq 35 + 35 + 12 + \sqrt{14^2} \leq 96 \text{ ns}$$

1) O-RAN/3GPP requirements:  
 130 ns → NR intra-band continuous carrier aggregation in FR2 (mm-Wave: 24.25...52.6 GHz), co-located RUs only  
 260 ns → NR intra-band continuous carrier aggregation in FR1 (Sub-6 GHz: 0.45...6 GHz)

# FRONTHAUL TIMING & SYNCHRONIZATION DESIGN

## TIME ALIGNMENT ERROR (TAE) BETWEEN TWO RUs CONNECTED TO DIFFERENT FHGs



- T-GM (Primary/Backup) (PRTC-B: |TE| ≤ 40ns)
- T-BC Class C (|cTE| ≤ 10 ns, |dTE<sub>L</sub>| ≤ 10 ns, cTE<sub>R</sub> ≤ 12 ns, dTE<sub>RL</sub> ≤ 14 ns)
- T-TSC Class B (|cTE| ≤ 20 ns, |dTE<sub>L</sub>| ≤ 20 ns)
- enhanced-RU (eRU) (|TE| ≤ 35 ns)
- PTPoE + SyncE (G.8275.1)
- 

### Resiliency & Holdover:

- FHGs are connected to multiple CAS
- CASs source time from two different T-GMs
- O-DUs source time from two different FHGs

$$\max|TAE| \leq \max TE(RU_A) + \max TE(RU_B) + cTE(FHG_A) + cTE(FHG_B) + cTER(CAS) + \sqrt{\max |dTEL(FHG_A)|^2 + \max |dTEL(FHG_B)|^2 + \max |dTERL(CAS)|^2}$$

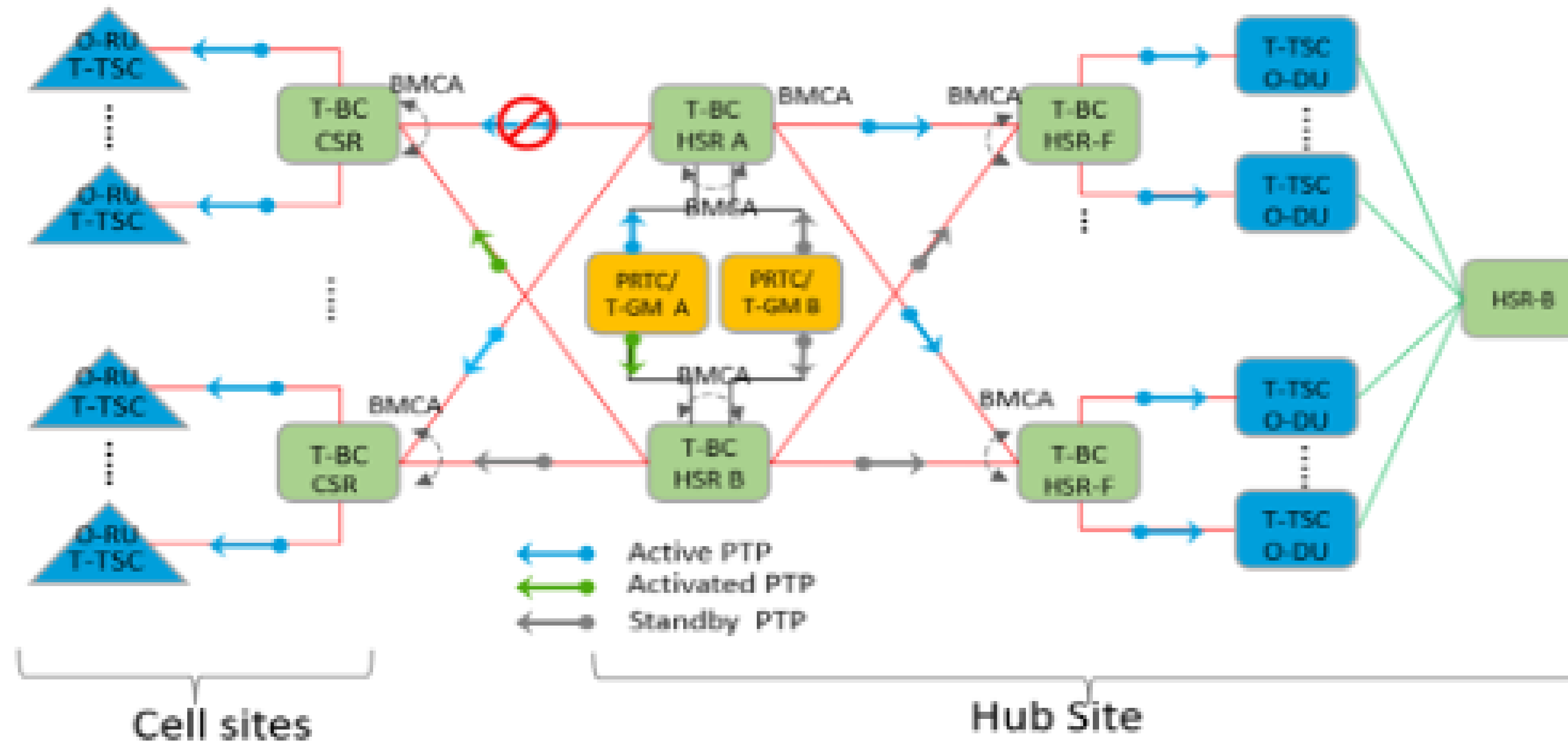
$$\max|TAE| \leq 35 + 35 + 10 + 10 + 12 + \sqrt{10^2 + 10^2 + 14^2} \leq 121.89 \text{ ns}$$

1) O-RAN/3GPP requirements:

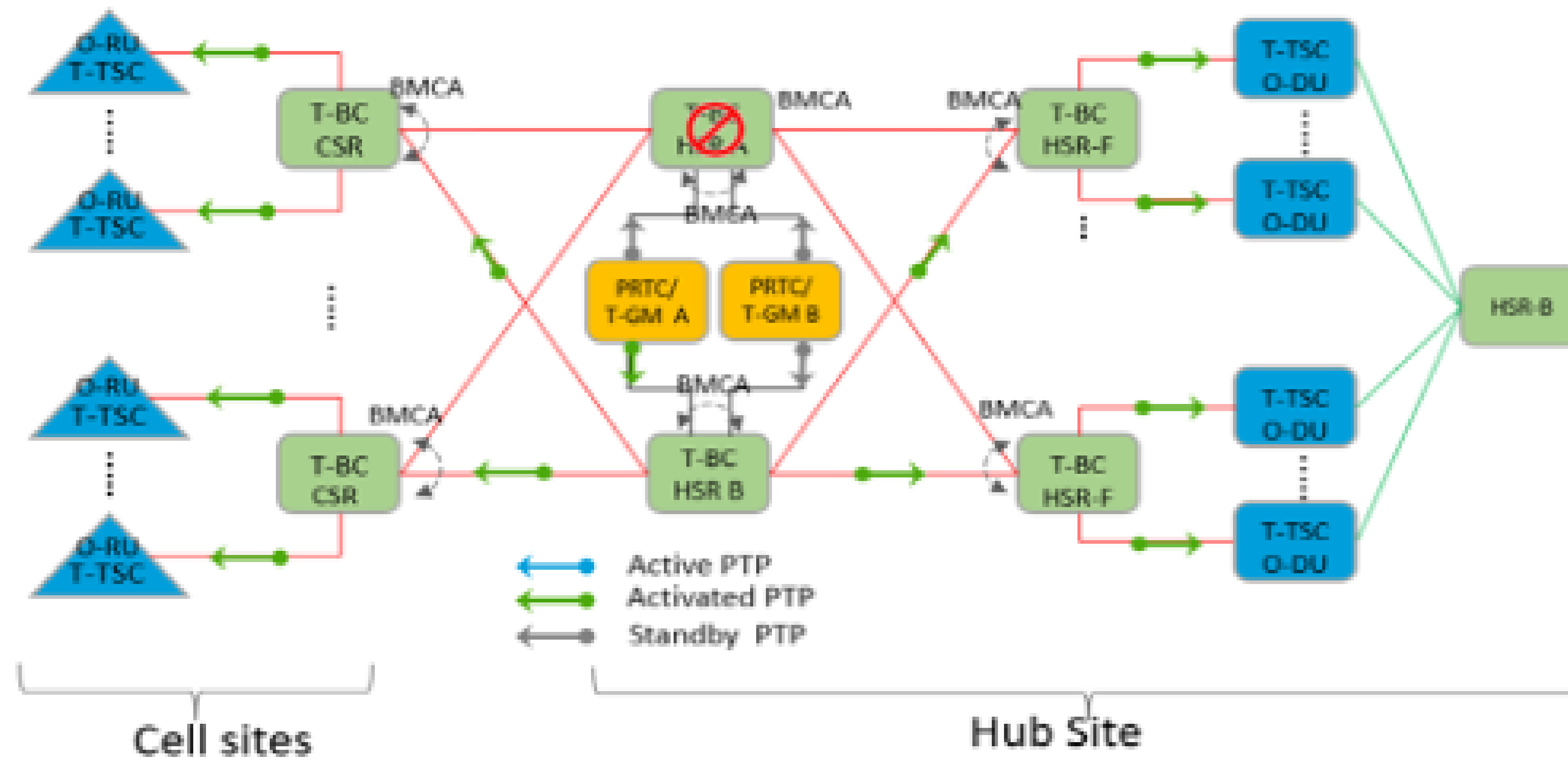
130 ns → NR intra-band continuous carrier aggregation in FR2 (mm-Wave: 24.25...52.6 GHz), co-located RUs only

260 ns → NR intra-band continuous carrier aggregation in FR1 (Sub-6 GHz: 0.45...6 GHz)

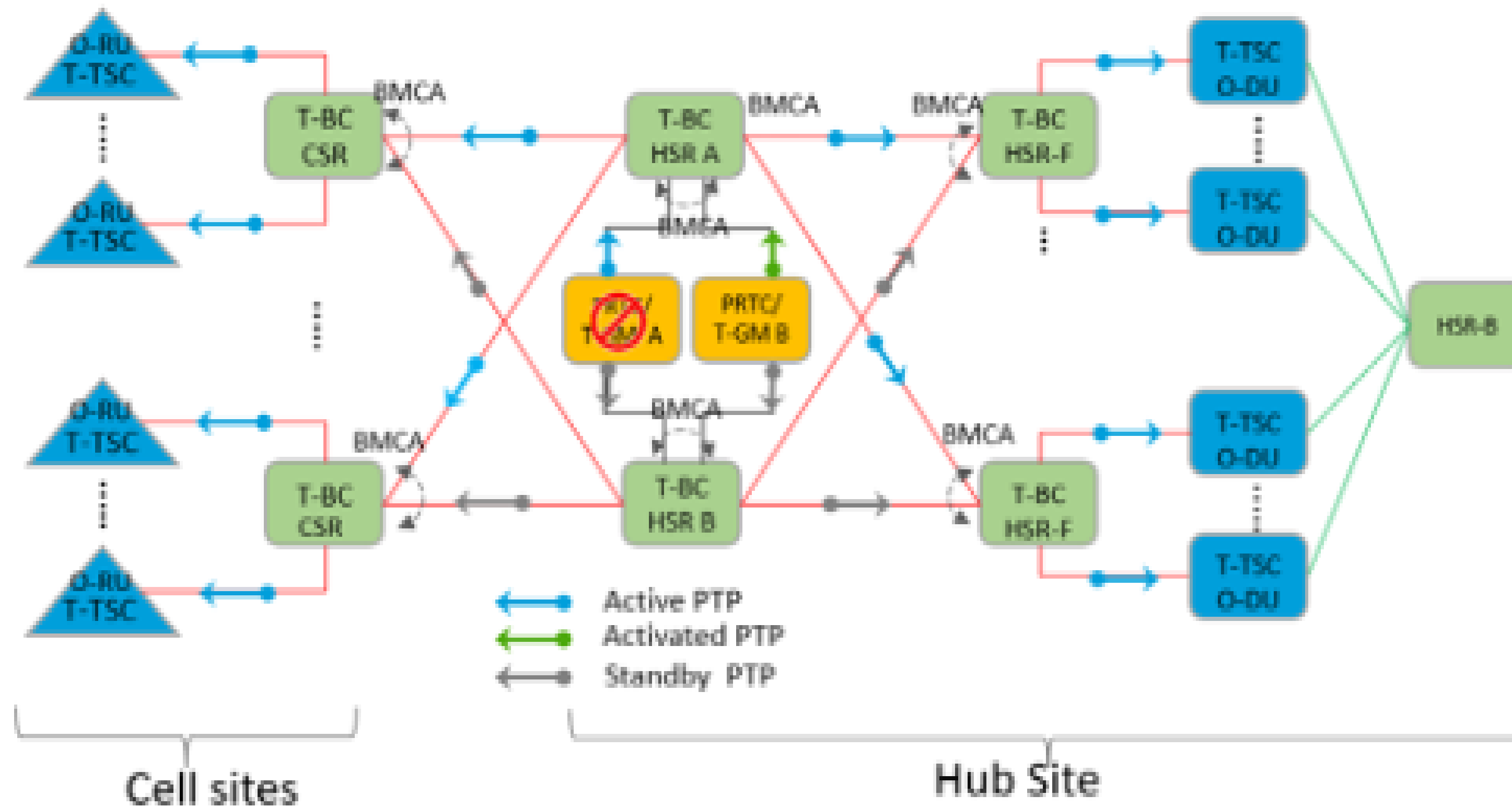
# DIFFERENT FAILOVER CONDITIONS – LINK FAILURE



# DIFFERENT FAILOVER CONDITIONS – NODE FAILURE



# DIFFERENT FAILOVER CONDITIONS – T-GM FAILURE





# SUMMARY

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- **Sync Network Resiliency is critical to address:**
  - The node & link failures
  - Mitigate the holdover
  - Mitigate the security attacks

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THANK YOU