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

Kamatchi Gopalakrishnan

Senior Distinguished Engineer

Satheesh Kumar S

Senior Staff Engineer

JUNIPER NETWORKS | Engineering Simplicity

AGENDA

- 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

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

O-RAN

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

Technical Specification

O-RAN Open X-haul Transport Working Group

Synchronization Architecture and Solution Specification

O-RAN

2 Contents

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| ≤ 3µs (cell radius < 3km) Relative |TAE| ≤ 10us (cell radius > 3km) (note 1) TS36.133	Timing Category C
Dual connectivity	Relative |TAE| ≤ 3µs (note 1) TS36.133	Timing Category C
MIMO or Tx Diversity	Relative |TAE| ≤ 65ns (note 2, note 4) TS36.104	
CA (intraband contiguous)	Relative |TAE| ≤ 130ns (note 2, note 5) TS36.104	Timing Category A (note 3)
CA (interband or intraband non-contiguous)	Relative |TAE| ≤ 260ns (note 2) TS36.104	Timing Category B (note 3)
OTDOA	Absolute |TAE| at O-RU antenna << 1.5us, ~100-200 ns (not defined by 3GPP)	Not covered since it is not defined by 3GPP

O-RU Air interface frequency error

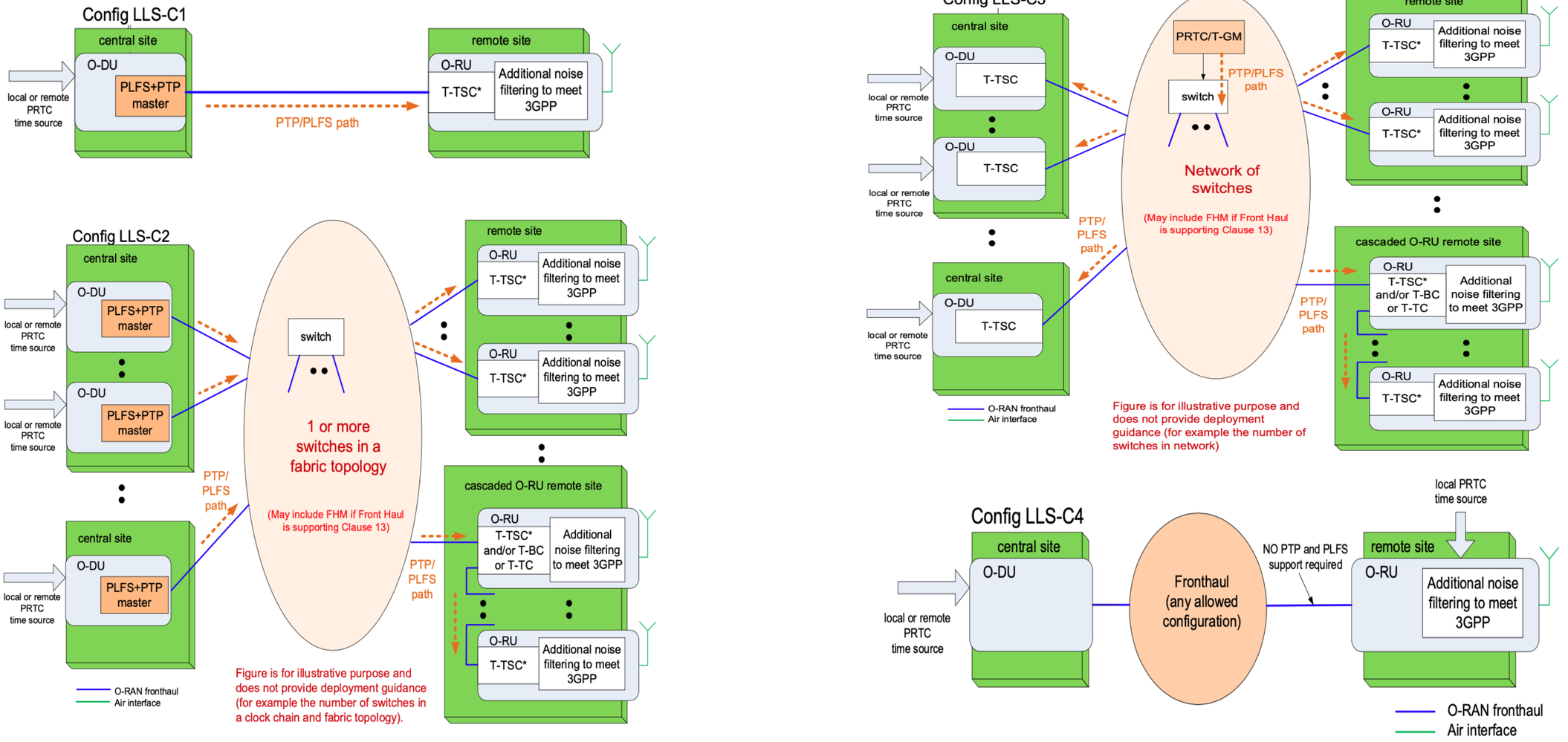
The O-RAN fronthaul network shall ensure O-RU meeting a **+/-50ppb** air interface frequency error requirement. 3GPP TS 36.104 (for LTE macro cells) and TS 38.104 (for 5G macro) specify +/-50ppb as the short-term average error in 1ms duration applicable to both LTE and 5G technologies.

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

SYNC CHALLENGES

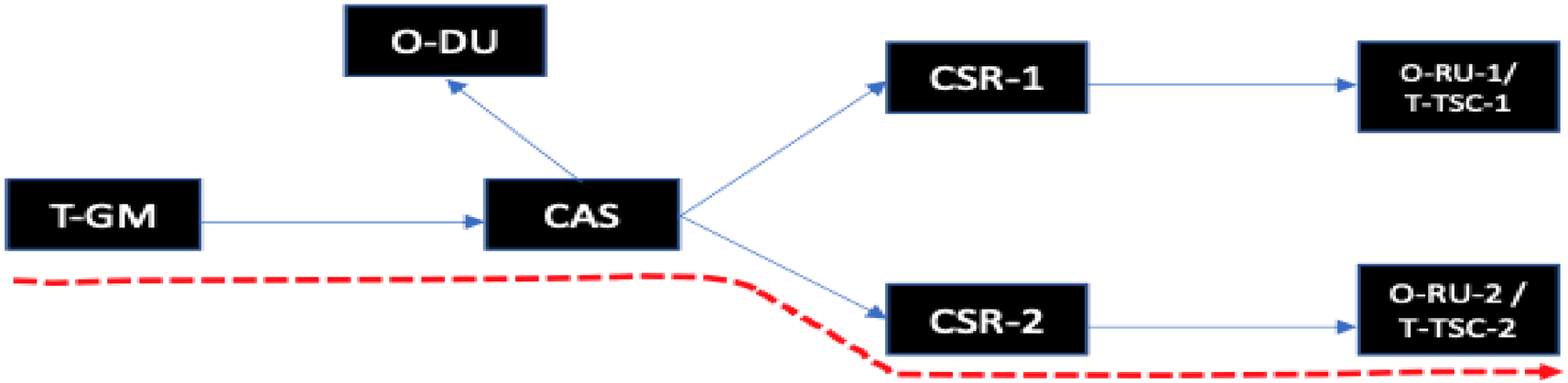
- Stringent TAE requirements
- Resiliency
- Holdover
- Security

ORAN CONFIG MODELS



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

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



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

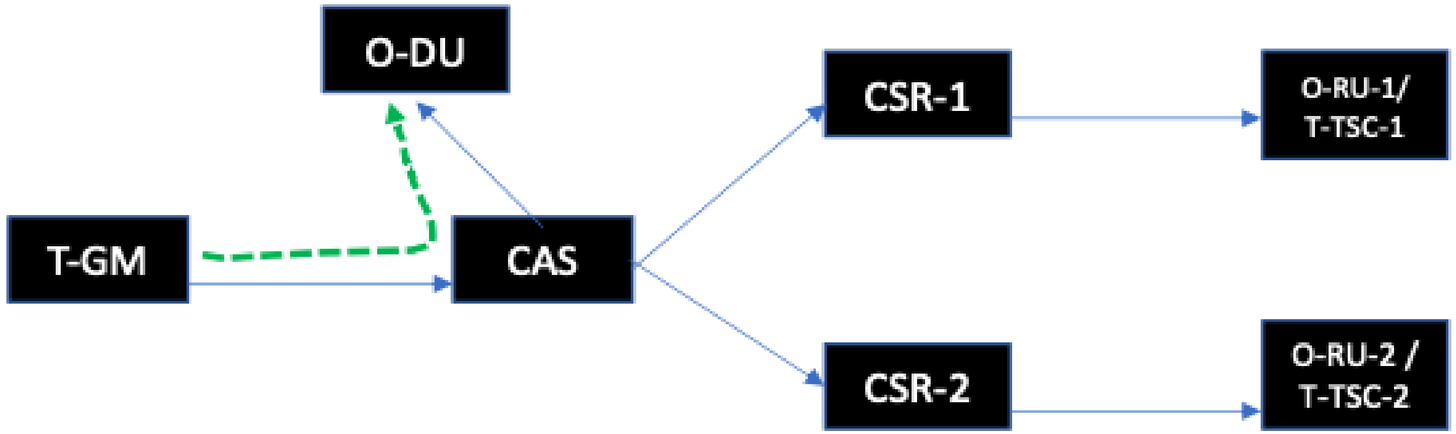
max|*TE*|	Maximum Absolute Time Error
cTE	constant Time Error
dTE_L	dynamic Time Error (low frequency)
dTE_H	dynamic Time Error (high frequency)
linkTE	Time Error introduced by link asymmetry

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| = maxTE(T-GM) + cTE(CAS) + cTE(CSR) + sqrt(max|$dTE_L(CAS)^2$ + $dTE_L(CSR)^2$|) + maxTE(O-RU)
- E2E max|TE| = 40 + 10 + 10 + sqrt($10^2 + 10^2$) + 35 => 109.14nsec => 109.14 nsec

CASE-2: T-GM TO O-DU

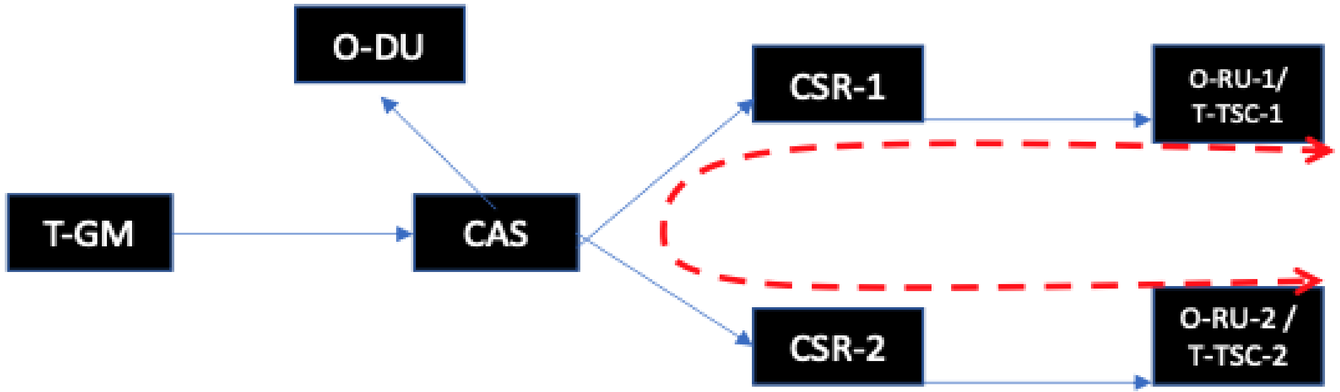


Assumptions:

- 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

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

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

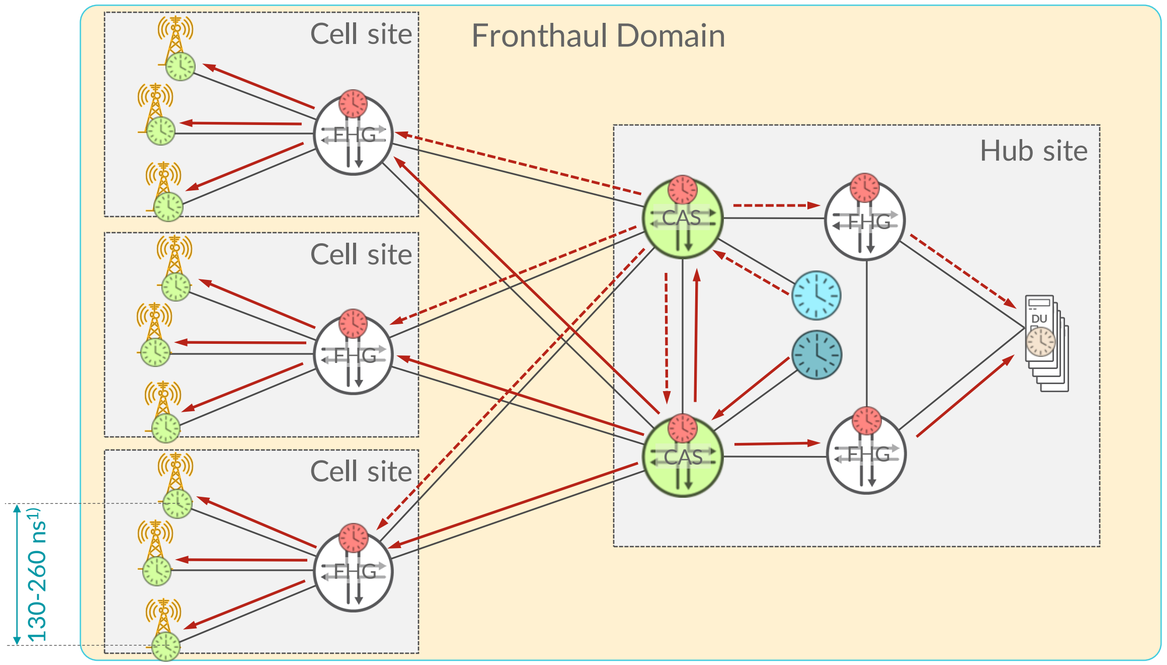


Assumptions:

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

- Relative $Max|TE| = maxTE(O\text{-}RU1) + maxTE(O\text{-}RU2) + cTE(CSR1) + cTE_R(CAS) + cTE(CSR2) + sqrt(max|dTE_{RL}(CAS)^2 + dTE_L(CSR1)^2 + dTE_L(CSR2)^2|)$
- Relative $max|TE| = 35 + 35 + 10 + 12 + 10 + sqrt(14^2 + 10^2 + 10^2) \Rightarrow 121.89$ 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, $|dTE_L|$ ≤ 10 ns
cTE_R ≤ 12 ns, dTE_{RL} ≤ 14 ns)

T-TSC Class B
(|cTE| ≤ 20 ns, $|dTE_L|$ ≤ 20 ns)

enhanced-RU (eRU)
(|TE| ≤ 35 ns)

PTPoE + SyncE (G.8275.1)

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

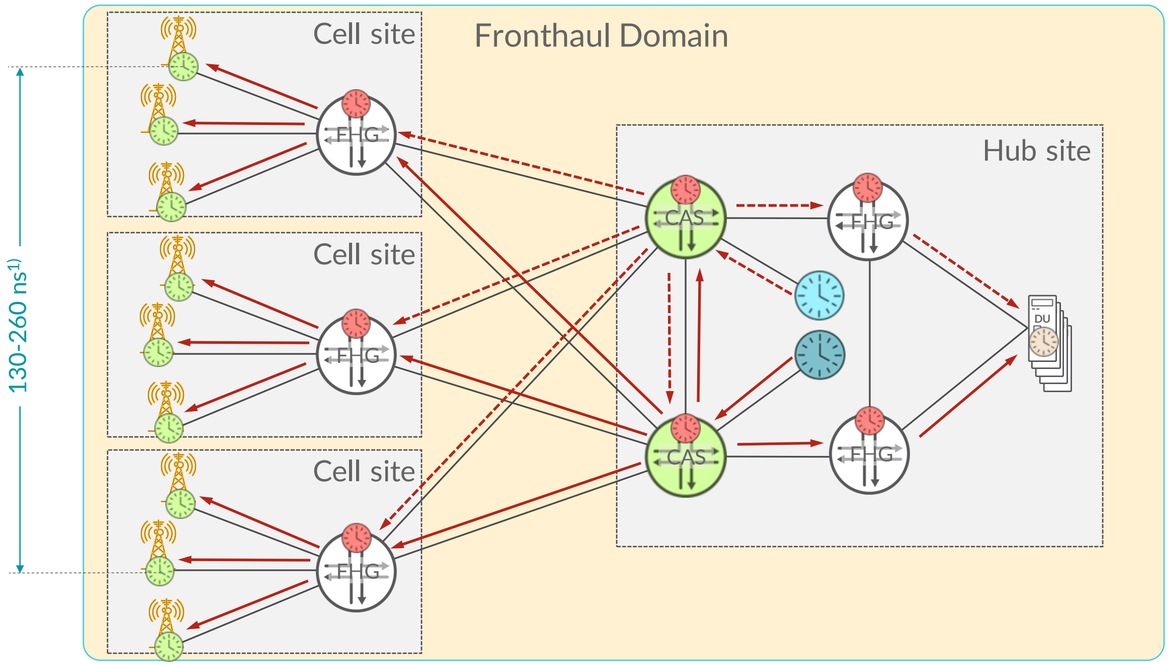
$$\max|TAE| \leq 35 + 35 + 12 + \sqrt{14^2} \leq 96\ ns$$

Resiliency & Holdover:

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

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, $|dTE_L| \leq 10$ ns
$cTE_R \leq 12$ ns, $dTE_{RL} \leq 14$ ns)

T-TSC Class B
(|cTE| ≤ 20 ns, $|dTE_L| \leq 20$ ns)

enhanced-RU (eRU)
(|TE| ≤ 35 ns)

PTPoE + SyncE (G.8275.1)

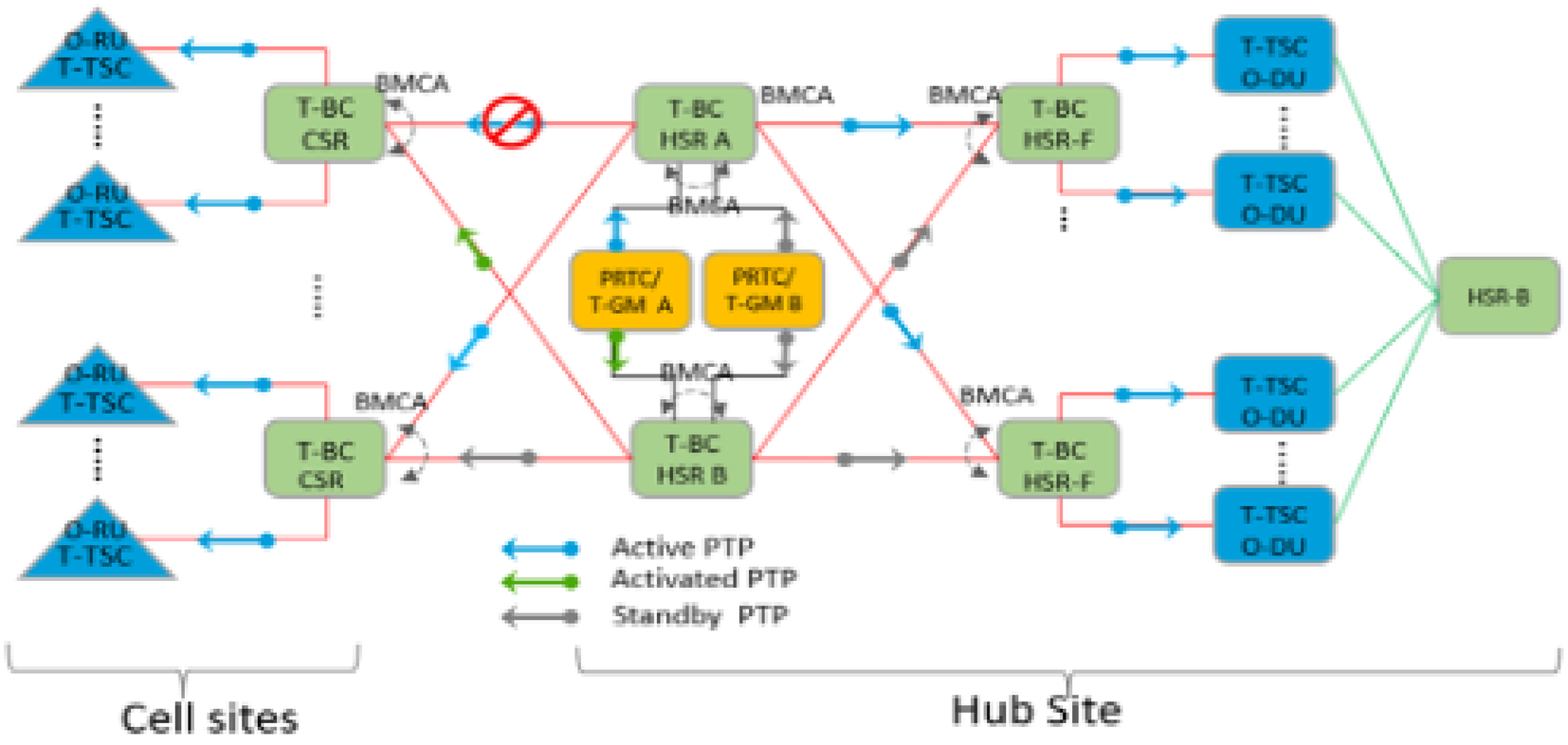
Resiliency & Holdover:
- FHGs are connected to multiple CAS
- CASs source time from two different T-GMs
- O-DUs source time from two different FHGs

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

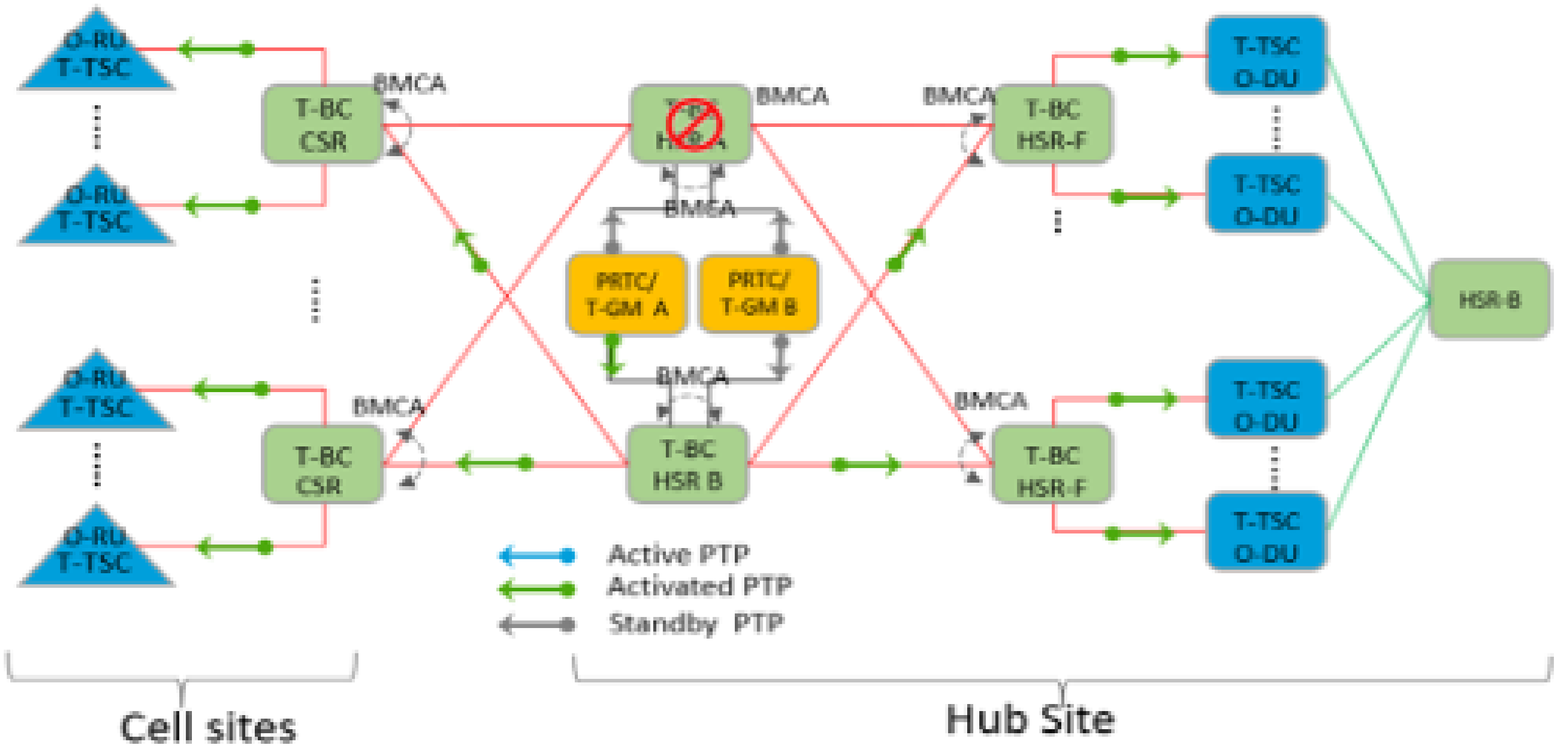
$$\max|TAE| \leq 35 + 35 + 10 + 10 + 12 + \sqrt{10^2 + 10^2 + 14^2} \leq 121.89\,ns$$

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)

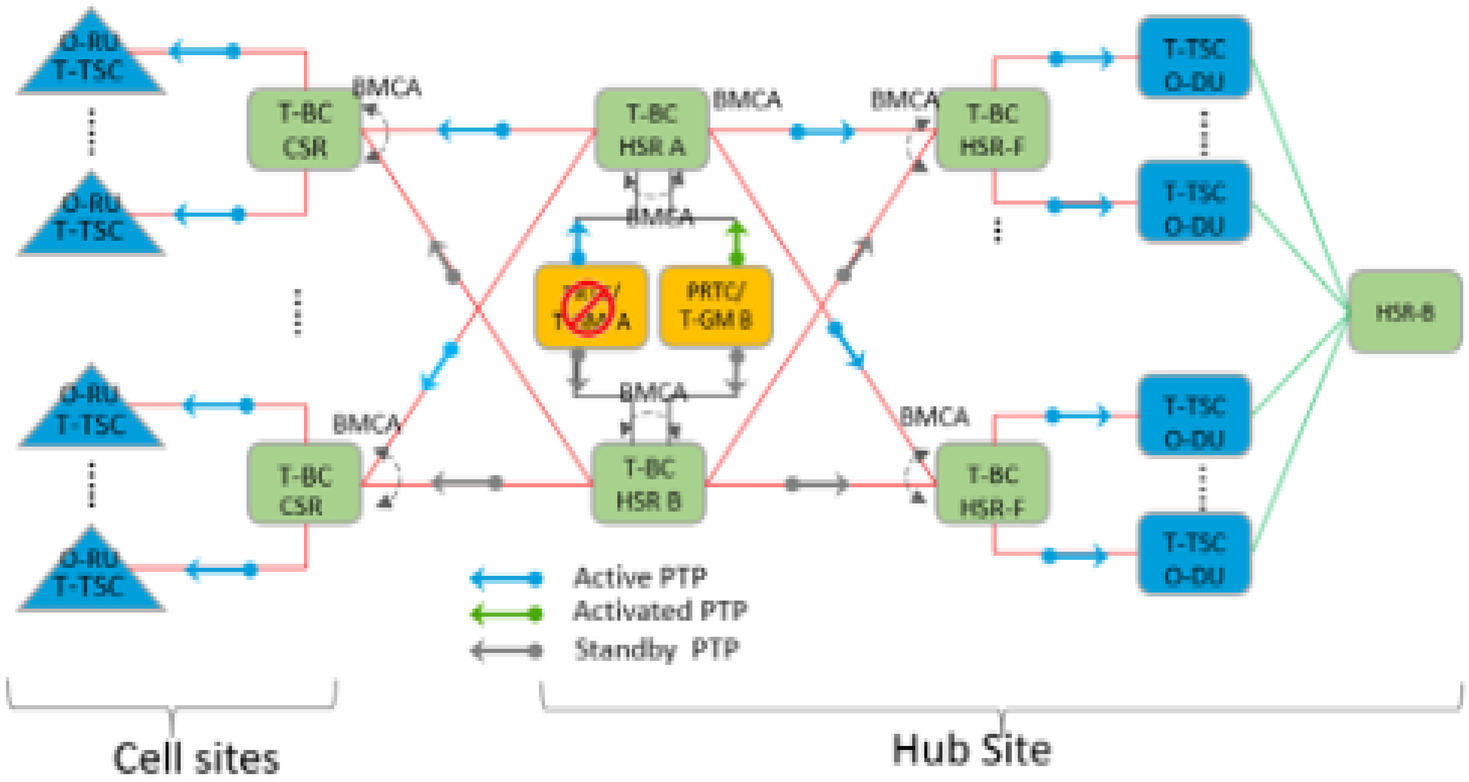
DIFFERENT FAILOVER CONDITIONS – LINK FAILURE



DIFFERENT FAILOVER CONDITIONS – NODE FAILURE



DIFFERENT FAILOVER CONDITIONS – T-GM FAILURE



SUMMARY

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

THANK YOU