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| **Change Request** | | | | | | | |
| **Document** | **ORAN-WG4.CUS.0** | **ver** | **06.00.00** | **CR** | **CAL-002** | **rev** | **0** | |

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| --- | --- | --- | --- |
| ***Title:*** | MTIE masks for S-plane | | |
| ***Source to WG:*** | Calnex Solutions Ltd. | | |
| ***Target WG :*** | **WG4** | | |
| ***Category:*** | **C** | ***CR Creation Date*** | 2021.05.25 |
|  | *Use one of the following* ***categories****:* ***A*** *(mirror corresponding to a change in an earlier release)* ***B*** *(addition of feature),* ***C*** *(functional modification of feature)* ***D*** *(editorial modification)* ***F*** *(correction)*  Detailed explanations of the above categories can be found in 3GPP [TR 21.900](http://www.3gpp.org/ftp/Specs/html-info/21900.htm). | | |

|  |  |
| --- | --- |
| ***Reason for Change:*** | The current document implies a specification in words, but that is not easy to translate into testable limits such as MTIE masks. This CR adds MTIE masks to Annex H for LLS-C1 and LLS-C2. It does not change the existing agreed specification, but shows how this specification can be translated into MTIE, providing clear and unambiguous test limits based on that specification to aid understanding and testability. |
| ***Summary of change:*** | See changes shown using tracked changes below. This consists mainly of the addition of a single block of text to Annex H, including tables and figures. |
| ***Consequences if not aproved:*** | The specification will be less clear for testing purposes. |

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| ***Clauses affected:*** | Section H.2 of CUS Specification v06.00. | | | | |
|  | **Y** | **N** |  | |  |
| ***Other specs*** |  | **N** | Other core specifications: | <fill in related CRs if “Y”> | |
| ***affected:*** |  | **N** | Test specifications: | <fill in related CRs if “Y”> | |
| ***(show related CRs)*** |  | **N** | O&M Specifications: | <fill in related CRs if “Y”> | |
| ***Supporting material:***  ***Other comments:*** | [CAL-2021-01-19 ORAN Reference Points and Network Limits.pptx](https://oranalliance.atlassian.net/wiki/download/attachments/1153105937/CAL-2021-01-19%20ORAN%20Reference%20Points%20and%20Network%20Limits.pptx?api=v2) (this was discussed during the S-Plane meetings) | | | | |

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| ***Status:*** | **Open** or **Closed** | ***CR Closed Date:*** | <CR closed date> |
| ***Outcome:*** | **Approved** or **Rejected** or **Deferred** | ***Duplication:*** | <dupl. CR number> |
| ***Outcome explanation:*** | <document editor provides the explanation of the outcome, especially justifying a “rejected” outcome (duplicate CR is a valid reason for rejection) > | | |

**< Provide here a description of the proposed change such as red-lined (or change-marked) text from the document. >**

[CAL-2021-01-19 ORAN Reference Points and Network Limits.pptx](https://oranalliance.atlassian.net/wiki/download/attachments/1153105937/CAL-2021-01-19%20ORAN%20Reference%20Points%20and%20Network%20Limits.pptx?api=v2) was a discussion document considered in the S-plane meetings. It showed how to interpret the existing synchronization specification outlined in section 9 and Annex H as a set of MTIE masks, defining the network limit at the output of the O-DU and the input to the O-RU.

This CR proposes to add the MTIE masks derived in that document to the discussion in Annex H of the CUS specification

The changes to Annex H are shown below in tracked changes. The original text shown is taken from [O-RAN-WG4.CUS.0-v06.00.00\_tc.docx](https://oranalliance.atlassian.net/wiki/download/attachments/1113490250/O-RAN-WG4.CUS.0-v06.00.00_tc.docx?api=v2), uploaded on March 11th, 2021. Subsequent CRs may have proposed changes to the original text since then.

The changes are mainly a single block of inserted text. The remaining changes are solely changes to Table numbers to preserve the number sequence.

# Annex H S-Plane detailed frequency and phase error budget analysis, and future ITU-T clock types and classes reference

## H.1 Reference documents

Section 9.2.1 includes the existing reference documents, and the following ones may be considered when available:

The following references from different standard organizations are work in progress. These upcoming references cover the future evolution over the above existing standard references to fully meet O-RAN synchronization needs.

* IEEE P802.1CM (committee draft 2.2 made available 7, May 2018 for passing Rev com) Time-Sensitive Networking for Fronthaul
* IEEE 1588 Draft Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems

At the time of releasing the O-RAN specification current revision, there is expectation but no binding commitment to include the new content of the above new specifications and revisions. Hence, when these specifications and new revisions are officially published, O-RAN must carefully review all the contents and determine their acceptance into O-RAN specification.

Section 9.2.4.2 specifies the PTP clock specification, and the following may be considered when available:

* A revision of IEEE 1588 was published by the end of 2019, and remains backward compatible with its 2008 edition. The use of new features in this revision may be recommended in future editions of this document.

## H.2 Frequency and time error budget analysis

This section provides the informative analysis to support budget allocation in Section 9.3.2 for a Full Timing Support network (as per ITU-T G.8271.1 for the limits, ITU-T.G.8273.2 for the clock definition). The analysis serves 2 purposes:

Considering T-BC Class B and C switches (as per ITU-T G. 8273.2) in a ITU-T G.8271.1 compliant network, the number of allowed switches to satisfy the allocated network limit is computed in detail as an example.

NOTE: the following configurations are outside the scope of this annex, and are therefore For Further Study:

* ITU-T G.8271.1 compliant networks using class D T-BCs.
* ITU-T G.8271.1 compliant networks using T-TCs instead of T-BCs.
* Non-ITU-T G.8271.1-compliant networks, such as ITU-T G.8271.2 ones.
* O-RU using SyncE/eSyncE. In the example below, only PTP is considered as synchronization source for O-RU.

Each network element in the fronthaul clock chain generates time error (including constant cTE and dynamic dTEH, dTEL), which will accumulate through the entire clock chain and be present at the O-RU UNI, as described in ITU-T G.8271.1 Appendix IV. This Annex consider the accumulation of centered, symmetrical noise. In particular, accumulated dynamic time error will cause O-RU subordinate clock FFO (fractional frequency error) after clock recovery and filtering. Given O-RU must meet the 3GPP air interface frequency accuracy target (±50ppb), O-RU filtering is needed to filter the accumulated dynamic time error and reduce the frequency error down to an acceptable level. The allowed network limit (i.e. dynamic time error), reasonable O-RU filter bandwidth and acceptable frequency error after filtering are the result of a compromise exercise as shown in the following analysis.

The value of the O-RU filtering bandwidth is a key compromise, combined with the local oscillator thermal sensitivity:

* The higher filtering bandwidth, the faster frequency correction of the local oscillator thermal sensitivity and therefore the lower temporary accumulated time error under thermal variations, but the poorer efficiency in low pass filtering the dynamic noise seen on the UNI
* The lower filtering bandwidth, the better efficiency in low pass filtering the dynamic noise seen on the UNI, but the poorer frequency correction of the local oscillator thermal sensitivity and therefore the higher temporary accumulated time error under thermal variations.

**Frequency error budget for Network limit (LLS-C1 and LLS-C2) :**

Based on the above compromise explanation, a practical expectation of O-RU filtering max BW is set to 75mHz to start the analysis.

Table H‑1 : O-DU Frequency Error Budget

|  |  |  |
| --- | --- | --- |
| **O-DU class** | **A** | **B** |
| * Consider O-DU PTP/SyncE master frequency error budget = …………….. (refer to note 1 in section 9.3.2.1) | ±15 ppb | ±5 ppb |
| * Consider O-RU total frequency error budget based on O-DU frequency error budget taken away from the 3GPP air interface (±50ppb) budget = ………… | ±35ppb | ±45ppb |
| * Further split the O-RU total frequency error budget as follows as an example of O-RU design:   + FFO (O-RU subordinate clock) =………………………………………………   + FFO (O-RU internal additive frequency noise) = ……………………… | ±21ppb ±14ppb. | ±27ppb ±18ppb |
| * With FFO (O-RU subordinate clock) value and filter BW = 75mHz, based on ITU-T SG15 Q13 C1730, Geneva, 5 – 16 December 2011:   ***FFO (in ppb) = ±2\*π \* |dTEL+H|(in ns)\*filter BW(in Hz)***   * FFO (O-RU subordinate clock) = 2π \* |dTEL+H| \* filter BW * |dTEL+H| = FFO (O-RU subordinate clock)/( 2π \* filter BW) = …………………… which is the max allowed network noise limit (between O-DU UNI and O-RU UNI) guaranteeing FFO at the output of the O-RU filter with 75mHz BW.   Note that after this network noise limit is agreed in O-RAN spec, it is up to O-RU vendor implementation to select filter BW (not necessarily 75mHz) to trade off the internal budget split between FFO (O-RU subordinate clock) and FFO (O-RU internal additive frequency noise) as long as the O-RU total frequency error budget (±35ppb or ±43ppb) is still met. | ±45ns | ±57ns |
| * Based on G.8271.1 Appendix IV guidance to calculate accumulated error: * Total dynamic noise = RMSsum (dTEL+H) * |dTEL+H| = RMSsum (|dTEL+H| of all nodes excluding O-RU’s T-TSC)   Consider the model of clock chain of n T-BC clocks (between O-DU UNI to RU UNI) ITU-T G.8273.2 (class B) switch: |dTEL| = 20ns, |dTEH| = 35ns   * | dTEL+H | limit = sqrt [n\*202 + 35²] ns = ……………………………………… * n = (|dTEL+H|² - 35²)/20², ………………………………………………………… the maximum number of class B T-BCs in each chain (excluding O-DU)   Consider the model of clock chain of n T-BC clocks (between O-DU UNI to RU UNI) ITU-T G.8273.2 (class C) switch: : |dTEL| = 5ns, |dTEH| = 10ns (Note 1)   * | dTEL+H | limit = sqrt [n\*52 + 10²] ns = ……………………………………… * n = (|dTEL+H|² - 10²)/5², ………………………………………………………… the maximum number of class C T-BCs in each chain (excluding O-DU)   Note 1: This |dTEH| limit is not yet specified by ITU-T G.8273.2 and is therefore an estimation. | ±45ns  2  ±45ns  >>10 | ±57ns  5  ±57ns  >>10 |

**Time error budget for network limit (LLS-C1 and LLS-C2) :**

Using existing class B T-BCs, and considering no time error contribution by the fiber asymmetry nor from two master ports of the same T-BC, then:

Following G.8271.1 Appendix IV guidance to calculate accumulated error with the following clock chain models:



Figure H‑1 : clock chain model for analysis

As per ITU-T G.8271.1 Appendix IV:

Total |TE| = sum (|cTE| of n nodes) + RSS sum (|dTEL| of n nodes and |dTEH| of last node)

= n\*|cTE| + sqrt (n\*|dTEL|2 + |dTEH|2)

However, the O-RU’s time error budget (cTE, |dTEL|2 + |dTEH|2) has already been taken into account in the budget (see tables below), so only the T-BCs in the network are included in “n” and their contribution is limited to cTE and dTEL.   
As a result, the above general formula can be further simplified for the chain of n T-BCs excluding the O-RU’s T-TSC:

Total |TEL| = n\*|cTE| + sqrt (n\*|dTEL|2),

Where a node is based on T-BC Class B switch with the following noise generation specification:

Constant time error = |cTE| = 20ns for class B, 10ns for class C

Low-band dynamic error = |dTEL| = 20ns for class B, 5ns for class C (considering centered noise)

Table H‑2 : O-RU Time Error Budget

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **For O-RU type= and limit =   to meet category  (notes 1, 2)** | **Enhanced 60ns Cat A** | **Regular 100ns Cat B** | **Enhanced 190ns Cat B** | **Regular 95ns Cat C** | **Enhanced 140ns Cat C** |
| n\*|cTE| + sqrt (n\*|dTEL| ²) < limit per branch | 30ns | 50ns | 95ns | 95ns | 140ns |
| maximum n value, number of class B T-BCs on each branch from common network element (either O-DU or T-BC) to O-RU: | 0 | 1 | 2 | 2 | 4 |
| Remaining relative TE margin to be assigned to fiber asymmetry and relative TE between two ports of the common network element | 60ns | 20ns | 53ns | 12ns | 20ns |
| maximum n value, number of class C T-BCs on each branch from common network element (either O-DU or T-BC) to O-RU: | 1 | 3 | 7 | 7 | 11 |
| Remaining relative TE margin to be assigned to fiber asymmetry and relative TE between two ports of the common network element | 15ns | 12ns | 12ns | 12ns | 14ns |

Note 1:

Proposed maximum n values are conservative and leave at least 10ns margin for fiber asymmetry or relative TEL between two ports of the branching clock. It is therefore recommended to limit the number of fronthaul clocks to this value, although an additional one may still allow meeting the expected limits.

Note 2:

- for IEEE802.1CM cat A and cat B, the limit corresponds to a relative TEL between two O-RU input ports (the end of two branches), and therefore the limit per branch is half.

- for IEEE802.1CM cat A and cat B, the limit corresponds to a relative TEL between the O-DU output and any O-RU input ports, and therefore the limit per branch is the same value.

**Network Limits for LLS-C1 and LLS-C2 based on the budget**

The above budget can be translated into network limits at various points in the network. This is useful for measurement purposes. For the LLS-C1 and LLS-C2 configurations, a simplified version of the synchronization network can be viewed as shown in Figure H-2 below. The numbers included are all quoted from Table 9-3, which is the normative source for LLS-C1 and LLS-C2..

PRTC

O-DU

O-RU

**G.8271.1 or G.8271.2 Network Limit** *(reference point C)*

**Max|FEL| ≤ 15ppb***(Class A O-DU)*   
or **5ppb** *(Class B O-DU)*;

**Max|TEL| ≤ 1325ns** *(LLS-C2)*

or **1420ns** *(LLS-C1)*

**Max|TEL| ≤ 1420ns**   
*(regular O-RU)*

or **1465ns** *(enhanced O-RU)*

**Network Max|TEL| ≤ 95ns** *(regular O-RU)* or **140ns** *(enhanced O-RU)*

**Network |dTEL+H| ≤ 45ns** *(Class A O-DU)* or **57ns** *(Class B O-DU);*

**Figure H‑2 : Simplified view of LLS-C1 and LLS-C2 configurations, with network limits**

The limit at the output of the O-DU can be described in terms of MTIE (Maximum Time Interval Error). This is given in Table H-3 and Figure H-3 (for a Class A O-DU) and Table H-4 and Figure H-4 (for a Class B O-DU). In both cases, these are measured after filtering by a first-order low-pass filter of bandwidth 0.1Hz (see Table 9-3, note 1).

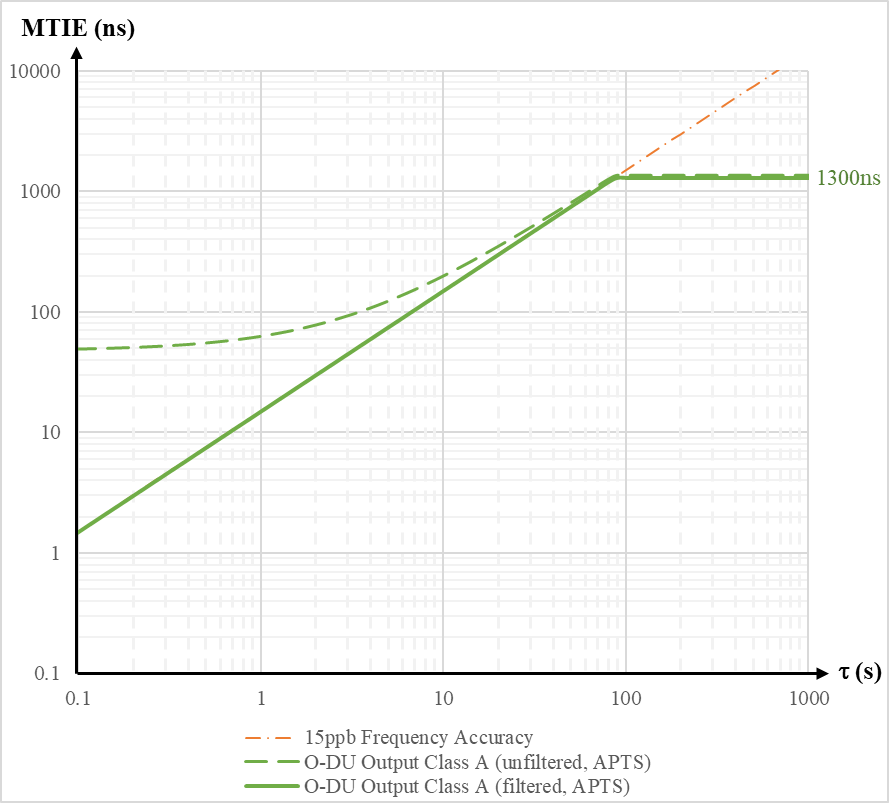
The maximum MTIE of 1300ns at long observation intervals is derived from the network limit in G.8271.2 of 1100ns (for an APTS network at the input to the O-DU), plus 200ns for the noise generation of the O-DU (based on the noise generation of a T-TSC-A in G.8273.4). This is the maximum MTIE value that should occur if the O-DU is synchronized using APTS. If the synchronization network at the input to the O-DU is FTS, while the slope of the MTIE graph at lower observation intervals will be the same, the maximum output should be much lower than the limit.

An unfiltered limit is also shown in each case, calculated by adding a constant value to the filtered limit representing the amount of noise that is expected to be removed by the measurement filter. The value to be added is calculated by using the equation quoted in Table H-1 above:

where FFO is the frequency accuracy budget of the O-DU, and *fm* is the bandwidth of the measurement filter. For an O-DU class A with a 15ppb frequency accuracy budget, and a measurement filter of bandwidth 0.1Hz, the |dTEL+H| is 24ns, resulting in an addition of 48ns to the filtered mask. For an O-DU class B, the addition to the mask is 16ns.

Table H‑3 : MTIE Limit at the output of an O-DU Class A

|  |  |  |
| --- | --- | --- |
| **Observation interval (s)** | **MTIE limit (0.1Hz filtered) (ns)** | **MTIE limit (unfiltered) ns** |
| 0.1 < τ ≤ 86.67 | 15 τ | 48 + 15 τ |
| τ > 86.67 | 1300 | 1348 |



**Figure H‑3 : MTIE Limit at the output of an O-DU Class A**

Table H‑4: MTIE Limit at the output of an O-DU Class B

|  |  |  |
| --- | --- | --- |
| **Observation interval (s)** | **MTIE limit (0.1Hz filtered) (ns)** | **MTIE limit (unfiltered) ns** |
| 0.1 < τ ≤ 260 | 5 τ | 16 + 5 τ |
| τ > 260 | 1300 | 1316 |

**Figure H‑4 : MTIE Limit at the output of an O-DU Class B**

Table H-1 makes assumptions about the bandwidth of the O-RU and the budget allocation for the FFO; however designers are free to change these assumptions provided the overall performance requirements at the RF output are met. The only figures for the amount of noise that are quoted in the normative section (Table 9-3) are the two |dTEL+H| figures of 45ns for an O-DU Class A, and 57ns for an O-DU Class B.

The maximum limit at the input to an O-RU can then be calculated by adding these figures to the unfiltered limit at the output of the O-DU. For a worst-case input, linear addition is assumed, adding 90ns for an O-DU Class A, and 114ns for an O-DU Class B. The tables below are for an unfiltered measurement:

Table H‑5 : MTIE Limit at the input to an O-RU (connected to an O-DU Class A)

|  |  |
| --- | --- |
| **Observation interval (s)** | **MTIE limit (unfiltered) ns** |
| 0.1 < τ ≤ 86.67 | 138 + 15 τ |
| τ > 86.67 | 1438 |

Table H‑6 : MTIE Limit at the input to an O-RU (connected to an O-DU Class B)

|  |  |
| --- | --- |
| **Observation interval (s)** | **MTIE limit (unfiltered) ns** |
| 0.1 < τ ≤ 260 | 130 + 5 τ |
| τ > 260 | 1430 |

These unfiltered limits are shown in Figure H-5 below in the dotted green and blue lines. The 15ppb and 5ppb lines are shown for information only. It is not possible to calculate a filtered version of these limits without assuming something about the frequency accuracy of the various noise contributions (e.g. the budget figures used in Table H-1), therefore the unfiltered limits are the primary limits.

It should be noted that the limit for a Class A O-DU is in all cases slightly higher than that for a Class B O-DU. Since when an O-RU is designed it is not known what class of O-DU it will be deployed with, the maximum noise that an O-RU must tolerate at its input is that for a Class A O-DU (the dashed green curve in Figure H-5 below):

**Figure H‑5 : MTIE limit at the input to an O-RU**

It should be noted that the MTIE limits shown in Figures H-3, H-4 and H-5 are not new requirements. They are derived from the existing requirements documented in Table 9-3, and hence are a way of expressing those requirements using MTIE. These limits should not create compatibility issues for existing equipment tested to the parameters in Table 9-3.

**Frequency error budget for Network limit (LLS-C3) :**

* Based on the above compromise explanation, a practical expectation of O-RU filtering max BW is set to 75mHz to start the analysis
* Based on G.8272, PRTC/T-GM MTIE (during lock) specification can be used to describe PRTC/T-GM dynamic noise generation:

Table H‑7 : Wander Generation (MTIE)

|  |  |
| --- | --- |
| **MTIE limit (us)** | **Observation interval (s)** |
| 0.275 x 10-3 τ + 0.025 | 0.1 < τ ≤ 273 |
| 0.10 | τ > 273 |

* Given O-RU filtering max BW = 75mHz, it corresponds to observation interval τ = 1/(π\*75mHz) = 4.2s.   
  From the above table, MTIE limit (with τ = 4.2s) = 26.2ns pk-pk.  
  From this MTIE number, the value of dTEL is computed as 13.1ns.
* Besides MTIE, which can be treated as dynamic noise during lock condition, there is additional consideration of PRTC/T-GM during holdover condition. Potential semi-static frequency drift could happen during holdover, ±2ppb is reserved based on ITU-T G.8271.1 Appendix V PRTC failure scenario (b) which permits 400ns holdover limit for short period of 5 minutes.

Table H‑8 : Network (LLS-C3) Frequency Error Budget

|  |  |
| --- | --- |
| **PRTC class** | **A** |
| Consider PRTC PTP/SyncE master frequency error budget =……………………………………… (refer to note 1 in section 9.3.2.2) | ±2 ppb |
| Consider O-RU total frequency error budget based on O-DU frequency error budget taken away from the 3GPP air interface (±50ppb) budget = …………………………………………………………. | ±48ppb |
| * Further split the O-RU total frequency error budget as follows as an example of O-RU design:   + FFO (O-RU subordinate clock) =…………………………………………………………… * FFO (O-RU internal additive frequency noise) = …………………………………… | ±30ppb ±18ppb |
| * With FFO (O-RU subordinate clock) value and filter BW = 75mHz, based on ITU-T SG15 Q13 C1730, Geneva, 5 – 16 December 2011:   ***FFO (in ppb) = ±2\*π \* |dTEL+H|(in ns)\*filter BW(in Hz)***   * FFO (O-RU subordinate clock) = 2π \* |dTEL+H| \* filter BW * |dTEL+H| = FFO (O-RU subordinate clock)/( 2π \* filter BW) = ………………………………… which is the max allowed network noise limit (between O-DU UNI and O-RU UNI) guaranteeing FFO at the output of the O-RU filter with 75mHz BW.   Note that after this network noise limit is agreed in O-RAN spec, it is up to O-RU vendor implementation to select filter BW (not necessarily 75mHz) to trade off the internal budget split between FFO (O-RU subordinate clock) and FFO (O-RU internal additive frequency noise) as long as the O-RU total frequency error budget (±35ppb or ±45ppb) is still met. | ±63ns |
| * Based on G.8271.1 Appendix IV guidance to calculate accumulated error: * Total dynamic noise = RMSsum (dTEL+H) * |dTEL+H| = RMSsum (|dTEL+H| of all nodes including PRTC/T-GM but not O-RU’s T-TSC) * Consider the model of clock chain of either class A or B PRTC/T-GM and n T-BC switches (between PRTC input to O-RU UNI) and using G.8272 MTIE specification for the PRTC and G.8273.2 dTEL+H specification for the T-BC. * PRTC/T-GM dynamic noise = MTIE/2 based on max 75mHz O-RU filter BW assumption: ………………………………………………………………………………. * T-BC Class B switch dynamic noise = |dTEL| = 20ns, |dTEH| = 35ns * |dTEL+H| = sqrt(132 + n\*202 +35²) ns= ……………………………………………………… * Maximum n= ( |dTEL+H|² - 35² - 13²) / 20² = ………………………………………………… the maximum number of class B T-BCs in each chain (after PRTC) * T-BC Class C switch dynamic noise = |dTEL| = 5ns, |dTEH| = 10ns * |dTEL+H| = sqrt(13² + n\*5² +10²) ns= ……………………………………………………… * Maximum n= ( |dTEL+H|² - 10² - 13²) / 5² = ……………………………………………… the maximum number of class C T-BCs in each chain (after PRTC) | 13ns  63ns  6  63ns  >>10 |

**Time error budget for network limit (LLS-C3):**

G.8271.1 Appendix V (Example of design options) and Appendix XII (Examples of design options for fronthaul and clusters of base stations) provide guidelines on the number of switches that can be deployed in case of LLS-C3 for the different target requirements.

Appendix V is focusing on the absolute Time Error Requirement (Category C), while Appendix XII addresses also relative time error requirements applicable in fronthaul (Category A and B).

## H.3 Summary of allowed number of switches:

The maximum allowed number of switches shall be determined based on the smallest allowed number constraint by

* Frequency error budget
* Operator-chosen most constraint time error budget category
* The class of network elements (note that the O-RU classes are examples proposed by IEEE802.1 CM)

Table H‑9 : Network Frequency Error Budget

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Frequency Error Network limit** | **LLS-C1 and LLS-C2, class A O-DU** | **LLS-C1 and LLS-C2, class B O-DU** | **LLS-C3** | **Comment** |
| Absolute Frequency error budget between time source and O-RU | 2  (class B T-BC)  >>10  (class C T-BC) | 5  (class B T-BC)  >>10  (class C T-BC) | Note 3 | Any branch must not exceed this number of T-BCs from O-DU or PRTC/T-GM to meet 50ppb frequency accuracy at the air interface. |

Table H‑10 : Network Time Error Budget

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Time Error Network limit** | **LLS-C1 and LLS-C2, class A O-DU** | **LLS-C1 and LLS-C2, class B O-DU** | **LLS-C3** | **Comment** |
| Cat A Relative Time error budget (with enhanced O-RUs) between O-RUs | 0  (class B T-BC)  1  (class C T-BC) | 0  (class B T-BC)  1  (class C T-BC) | Note 3  Note 4 | Any branch must not exceed this number of T-BCs from common T-BC to meet target relative time error limit at the air interface.  Value 0 means that only lls-C1 is supported |
| Cat B Relative Time error budget (with regular O-RUs) between O-RUs | 1  (class B T-BC)  3  (class C T-BC) | 1  (class B T-BC)  3  (class C O-RU) | Note 3 |
| Cat B Relative Time error budget (with enhanced O-RUs) between O-RUs | 2  (class B T-BC)  7  (class C T-BC) | 2  (class B T-BC)  7  (class C T-BC) | Note 3 |
| Cat C Absolute Time error budget (with regular O-RUs) between time source and O-RU | 2  (class B T-BC)  7  (class C T-BC) | 2  (class B T-BC)  11  (class C T-BC) | Note 3 | Any branch must not exceed this number of T-BCs from O-DU or PRTC/T-GM to meet 1500ns absolute time error limit at the air interface.  Note 1. |
| Cat C Absolute Time error budget (with enhanced O-RUs) between time source and O-RU | 4  (class B T-BC)  (further limit to 2 due to freq. limit)  7  (class C T-BC) | 4  (class B T-BC)  11  (class C T-BC) | Note 3 |

Note 1 : Only applicable to lls-C1 and lls-C2: As indicated in table 9-3, the maximum Time Error at the output of the O-DU is 1420 ns for lls-C1 and 1325 ns for lls-C2. This limit considers that the input of the O-DU stays within the limits at Reference point C defined by ITU-T G.8271.1 or ITU-T G.8271.2 .

Note 2 : The analysis on the number of switches (for time error budget) is meant to rough estimate and excludes both fiber asymmetry factor and relative TE between two ports of the common network element. It is operator’s responsibility to control these two parameters. The analysis for each time error budget (specific category) has some left-over margin that could be used to cover them. If the left-over margin is not enough, the alternative is to reduce the allowed number of switches.

Note 3: network design guidelines for configuration LLS-C3 are provided in ITU-T G.8271.1 Appendix V (addressing IEEE802.1CM synchronization Category C) and Appendix XII (addressing IEEE802.1CM synchronization Category A and B) of G.8271.1. The guidelines in Appendix V includes also indication on allowed number of switches between the PRTC/T-GM and the O-RU. The guidelines in Appendix XII include also indication on allowed number of switches between a clock that is common for the cooperating O-RUs, and these O-RUs.

As an example:

- in order to meet the Cat B requirements with a regular O-RU, the number of T-BC class C switches, after the common switch (itself a class C T-BC), should be 3 or less, while there is no room for additional switches with T-BC class B clocks after the common switch (itself a class B T-BC).

- In order to meet the Cat B requirements with an enhanced O-RU, the number of T-BC class C switches should be 6 or less after the common switch (itself a class C T-BC), and the number of T-BC class B switches after the common switch (itself a class B T-BC), should be 2 or less.

The minor differences between the maximum number of switches supported in LLS-C2 and LLS-C3 are due to different characteristics of the common clock (as indicated in Figure H-1, in LLS-C2, the O-DU has no relative time error between ports specified, while in LLS-C3, the G.8273.2 T-BC takes this into account).

G.8271.1 also presents the case of an alternative deployment with a short clock chain that has a maximum of 4 Class C T-BC, or 1 Class B T-BC between the PRTC/T-GM and the O-RU (see reference network model in Figure II.6 of G.8271.1 with a PRTC-B/T-GM directly connected to the common T-BC). For this case the regular O-RU was considered as it represents the worst-case scenario. This deployment, in addition to meeting IEEE802.1CM synchronization Category C, is also suitable to support IEEE802.1CM synchronization Category B.

Note 4: Cat A requirements concerns co-located O-RUs. It is assumed that the cooperating O-RUs are connected to the same switch (therefore there is no switch after the common T-BC).