

O-RAN O-DU Testing

Testing O-DUs for LLS-C1, LLS-C2, LLS-C3 and LLS-C4 deployment as per O-RAN requirements using Paragon-neo

- WG4.CONF v09.00 3.3.5 Functional test
- WG4.CONF v09.00 3.3.6 Functional test
- WG4.CONF v09.00 3.3.7 Performance test
- WG4.CONF v09.00 3.3.8 Performance test



The synchronization (S-plane) functional and performance requirements of an O-DU are defined mainly in the O-RAN CUS and CONF specifications.

Validating an O-DU against these requirements is essential in ensuring that the device will interoperate as expected when deployed in an O-RANcompliant environment. This is a critical consideration in the open, mixedvendor environment that O-RAN enables.

This guide describes how to test an O-DU using Paragon-neo to ensure its behaviour meets the requirements specified in the CONF document for devices to be deployed in an LLS-C1, LLS-C2, LLS-C3 or LLC-C4 topology.

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1. Hardware and Software Required

Paragon-neo

Opt. NEO-1G-10G*	1/10GbE interface support (if the O-DU has 1G and/or 10G interfaces)
Opt. NEO-25G*	25GbE interface support (if the O-DU has 25G interfaces)
Opt. NEO-40G*	40GbE interface support (if the O-DU has 40G interfaces)
Opt. NEO-50G*	50GbE interface support (if the O-DU has 50G interfaces)
Opt. NEO-100G*	100GbE interface support (if the O-DU has 100G interfaces)
Opt. NEO-A-PAM4-50G	PAM4 50GbE interface support (if the O-DU has PAM4 50G interfaces)
Opt. NEO-A-PAM4-100G	PAM4 100GbE interface support (if the O-DU has PAM4 100G interfaces)
Opt. NEO-A-PAM4-200G	PAM4 200GbE interface support (if the O-DU has PAM4 200G interfaces)
Opt. NEO-A-PAM4-400G	PAM4 400GbE interface support (if the O-DU has PAM4 400G interfaces)
Opt. NEO-PTP-G.8275.1*	Emulation of G.8275.1 PTP timeTransmitter and timeReceiver devices, with associated Time Error Impairment and measurement capability
Opt. NEO-SyncE-Wander*	(if the O-DU makes use of SyncE)
Opt. NEO-ToD	(If the O-DU makes use of a 1PPS+ToD input)

*Also available on PAM4-enabled Paragon-neo A units. Please replace the NEO- with NEO-A for the PAM4 version.

Paragon-neo software version:	11.00.xx or later
Paragon-neo A software version	11.00.xx or later

Accessories

- Optical Transceivers as required
- Cables and fibers as required

Document References

- O-RAN.WG4.CONF.0-R003-v09.00 O-RAN Working Group 4 (Fronthaul Working Group) Conformance Test Specification
- O-RAN.WG4.CUS.0-R003-v13.00 O-RAN Working Group 4 (Open Fronthaul Interfaces WG) Control, User and Synchronisation Plane Specification
- IEEE Std 1588[™] 2008 IEEE Standard for a Precision Clock Synchronisation Protocol for Networked Measurement and Control Systems
- IEEE Std 1588[™] 2019 IEEE Standard for a Precision Clock Synchronisation Protocol for Networked Measurement and Control Systems
- Recommendation ITU-T G.8275.1 Precision time protocol telecom profile for phase/time synchronization with full timing support from the network
- Recommendation ITU-T G.8275.2 Precision time protocol telecom profile for phase/time synchronization with partial timing support from the network
- Recommendation ITU-T G.8273.2 Timing Characteristics of Telecom Boundary Clocks
- Recommendation ITU-T G.8273.3 Timing characteristics of telecom transparent clocks for use with full timing support from the network
- Recommendation ITU-T G.8262 Timing characteristics of synchronous equipment slave clock
- Recommendation ITU-T G.8262.1 Timing characteristics of enhanced synchronous equipment slave clock
- Calnex Test Guide: CX3016 Paragon-neo PRTC Test Guide
- Calnex PFV Getting Started Guide
- Calnex Paragon-neo Getting Started Guide

Further Reading

- Calnex Application Note: Cabling Considerations (CX5009)
- Calnex O-RAN Technical Primer: <u>https://www.calnexsol.com/en/timing-and-sync-blog-article-display/1518-how-is-the-network-changing-and-what-does-this-mean-for-sync</u>

2. Document Information

It should be noted that the performance tests in this guide focus on the quality of the timing output from the device-under-test as specifically defined in the relevant standards and recommendations.

However, during product development or qualification, other aspects of device behaviour and performance may be of interest. Such aspects could include:

- Device warm-up time and duration required to achieve optimal performance with both ideal and non-ideal reference inputs.
- Performance under various input reference impairment profiles, failure modes and the subsequent recovery times
- Device performance changes depending on the order, concurrency, and duration of multiple fail events.
- Type and quality of events reported by the device via the management interfaces.
- Accuracy of on-device timing performance monitoring and reporting functions.

In the case of the above being of interest, the test procedures in this document can be used as a basis for you to design your own tests to study those aspects.

The Calnex Sentinel and Paragon-x products can be used to capture real-life network performance and can be imported into Paragon-neo as impairment profiles.

3. Introduction to the Tests

An Open Radio Access Network (Open RAN) is a non-proprietary version of the Radio Access Network (RAN) system that allows interoperation between cellular network equipment provided by different vendors. The concept behind Open RAN is that by standardizing the main elements of the network and defining interoperable interfaces between those elements, the network designer will have a greater choice of components to deploy.

The O-RAN Alliance (O-RAN) defines the performance and interface specifications for the component parts, ensuring interoperability and overall network behaviour.

3.1. O-RAN Main Elements



3.2. O-RAN Fronthaul Interoperable Elements



3.3. O-RAN Fronthaul LLS Architectures

O-RAN specifies four types of synchronization architectures for the fronthaul Lower Layer Split (LLS), these are shown below. The conformance test scenarios and pass criteria can be different depending on the architecture(s) the O-DU will be deployed in.



3.4. O-DU S-Plane Capability Requirements

The overall synchronization performance of an O-DU is defined in the O-RAN Working Group 4 (Open Fronthaul Interfaces WG) Control, User and Synchronisation Plane Specification document O-RAN.WG4.CUS.O-R003-v13.00, Section 11, with additional information in Annex H.

O-RAN defines multiple architectures and synchronisation methodologies, to enable the greatest utility of the O-DU and to guarantee full interoperability and applicability to all deployment scenarios the O-DU should be tested for all relevant capabilities specified in O-RAN.WG4.CUS. The capabilities defined in O-RAN.WG4.CUS are:

Table 1: O-DU Capabilities

Capability / Conformance	O-RAN.WG4.CUS Reference	Notes
ITU-T G.8275.1	Table 10.2-1	See referenced table for conditions.
ITU-T G.8275.2	Table 10.2-1	See referenced table for conditions.
ITU-T G.8272/.1 (PRTC)	Clauses 11.3.1.1, 11.1.3.2	If O-DU implements an embedded GNSS receiver.
ITU-T G.8273.2 (T-BC)	Clauses 11.2.2.1, 11.3.1.1, 11.3.1.2	See referenced clauses for conditions.
ITU-T G.8273.3 (T-TC)	Clause 11.3.1.1	See referenced clause Note 2, if O-DU implements TC
ITU-T G.8262/.1 (EEC/eEEC)	Clauses 11.2.4,1, 11.2.5.2, 11.2.5.3	PLFS implementations must implement SyncE.

S-plane conformance tests for the O-DU are described in the O-RAN Fronthaul Working Group Conformance Test Specification document *O-RAN.WG4.CONF.v09.00*, clause 3.3.

Functional tests are described in clause 3.3.5 and 3.3.6, these are mandatory for all O-DU's.

The performance tests in clause 3.3.7 are mandatory for O-DU's that support LLS-C1, LLS-C2 deployment configurations and do not only derive their timing from an embedded PRTC. The tests are optional for O-DU's that only support LLS-C3 and LLS-C4 deployment configurations.

The performance test in clause 3.3.8 performance test is mandatory if the O-DU contains an embedded local PRTC using a GNSS receiver.

Currently not all O-DU capabilities specified in O-RAN.WG4.CUS are tested by the methodologies in O-RAN.WG4.CONF. Calnex provide the following Test Guides for use in testing device conformance to the relevant capabilities:

Capability / Conformance	Calnex Test Guide
ITU-T G.8275.1 / G8273.2 (T-BC)	CX3009 G.8273.2 BC Conformance Test
ITU-T G.8275.2	CX3013 G.8273.4 Conformance Test
ITU-T G.8272/.1 (PRTC)	CX3016 Paragon-neo PRTC Test Guide.
ITU-T G.8275.1 / G.8273.3 (T-TC)	Currently being authored, contact Calnex for further details.
ITU-T G.8262 / G.8262.1	G.8262.1/G.8262 EECs Conformance Test

Table 2: Calnex Test Guides

4. Connecting Paragon-neo to the Device-Under-Test

Detailed information regarding the Paragon-neo front panel connections and interfaces are detailed in the *Calnex Paragon-neo Getting Started Guide* that is provided as part of the Paragon-neo on-instrument document set. It is accessible from the **Help** menu in the top right of the Paragon-neo's Graphical User Interface (GUI).

4.1. Connections for O-DU Conformance

The high-level connectivity diagrams for testing O-DU conformance are shown below. This does not include the connectivity for an O-DU with an embedded GNSS receiver, information about the connectivity for testing this implementation can be found in the Calnex Test Guide: *CX3016 Paragon-neo PRTC Test Guide*.

O-DU Measuring PTP and SyncE Output

The configuration below measures the PTP, SyncE and 1PPS+ToD from the O-DU.



Detailed Test Topology

A detailed overview of the test topology when using Paragon-neo is shown in Figure 1 below.



Figure 1: O-DU detailed topology using Paragon-neo

Connections

- 1. Connect Port 1 (timeTransmitter side of Paragon-neo) to the O-DU timeReceiver side.
- 2. Connect Port 2 (timeReceiver side of Paragon-neo) to the O-DU timeTransmitter side.
- 3. If desired, connect the 1PPS+ToD Test Out from Paragon-neo to the O-DU 1PPS+ToD input.
- 4. If necessary, connect an external reference, e.g. 10MHz, to the Paragon-neo Reference Input.
- 5. If provisioned on the DUT, connect the 1PPS output from the O-DU to the Paragon-neo 1PPS measurement port.

If more details are required, please see the Paragon-neo Getting Started Guide.

5. Setting up Paragon-neo for O-DU CONF Testing

This does not include the connectivity for an O-RU with an embedded GNSS receiver, information about the connectivity for testing this implementation can be found in the Calnex Test Guide: *CX3016 Paragon-neo PRTC Test Guide*.

Prior to performing the O-DU testing, the following steps should be performed:

- 1. Connection to Paragon-neo
- 2. Configuration of physical connections
- 3. Test configuration
- 4. Device connection settings

5.1. Connection to Paragon-neo

- 1. Verify the physical connections have been completed as described in Section 4 for the relevant test type.
- 2. From a PC on the same network, open a browser and enter the IP address of the Paragon-neo unit.

If more details are required, please see the Paragon-neo Getting Started Guide.

5.2. Configuration of Physical Connections

- 1. Select the Setup Ports page, then using the displayed GUI, select the Reference, Test, and Interface ports to be used.
- 2. If required, configure appropriate values for the **Threshold**, **Termination** and **Serial** parameters for the reference and measured 1PPS or 1PPS+ToD signals. Threshold voltages should be set to two decimal places (i.e., *x.yy* Volts) to ensure the best accuracy of test and measurement.
- 3. Ensure that all relevant status indicator soft LEDs on the right of the GUI are green, indicating the configuration matches the physical setup. If any are red, review the setup and ensure all are green before progressing.



5.3. Test Configuration

Select the **Run Apps** page. if the presets are not already displayed, expand the **Presets** panel, then select the **O-RAN Conformance Test** preset.



5.4. Device Connection Settings

The tests covered by this document specify the Full Timing Support profile, G.8275.1 therefore this guide assumes that conformance testing will use this PTP configuration.

Physical Layer Frequency Support (PLFS), typically SyncE, is mandatory when using G.8275.1 however WG4.CUS clause 11.2.3 states: "... an O-DU or O-RU end application is not required to use a PLFS to achieve clock (frequency) synchronization..." The configuration of Paragon-neo should therefore match the requirements of the O-DU with regards to providing a SyncE input.

- 1. In the **O-RAN Conformance Test** app, select **O-DU Ideal** as the test. This will automatically select the Boundary Clock Test Mode and PTP Profile G.8275.1.
- 2. In the PTP Emulation app, select the appropriate PTP Standard for the O-DU.



3. Select **Test Config** and enter cable delay values appropriate for the test setup. Delay values are represented in nanoseconds and should be entered to two decimal places (i.e. *x.yy*) for best results. A value of 4.9ns per meter of single-mode optical fiber and 4.94ns/m of multi-mode fiber is typical, but for the best accuracy of device measurement, the specific value for the fiber used should be confirmed as per its datasheet. For the coaxial cable used for 1PPS (unbalanced) signals, values of 4.5 to 5.1ns per meter are typical; this should be confirmed by datasheet or vendor. Once correct values have been entered, click **Apply**.



4. If the O-DU requires a 1PPS+ToD input, select the appropriate Time of Day message format.



 If a 1PPS or 1PPS+ToD signal is to be measured, enter the measurement cable delay value in the 1PPS Time Error Measurement + Time of Day app, then click Apply. if Apply has not been clicked, the field will be yellow as shown below:

1pps Time Error Measurement + Time of	Day	_	
Elapsed Time 00d 00h 00m 00	. РГ/ Сат	1pps Measurement cable compensation: 32.53 ns Timing Period: Manual V Apply 1pps Reference cable compensation: 0 ns	

6. If the O-DU makes use of SyncE, in the **ESMC Generation** app, configure the SSM code (SyncE QL value) to an appropriate value such that the O-DU will use Paragon-neo as a frequency reference. Typical values for this are QL-PRC or QL-ePRC.

ESMC Generation ((Port1)		
GENERATE	Enhanced SSM ✓ Network Option: Option 1 ✓ SSM Code: QL-ePRC ✓ Event Flag ☑	Partial Chain Mixed EEC/eEEC Cascaded eEECs: 0 Cascaded EECs: 0 SyncE Clock Id: 00:00:00:00:00:00 Inter-packet Gap: 1000 ms MAC Address: 00:00:00:00:2b	

6. O-DU CONF 3.3.5 and 3.3.6 Functional Tests

These tests are mandatory. Their purpose is to validate that an O-DU is correctly synchronizing to a PTP and (optionally) SyncE source using ITU-T G.8275.1 profile, or a 1PPS+ToD signal, and that the O-DU correctly reports its status based on the nominal or degraded synchronization conditions.

The PTP and SyncE outputs from the O-DU should be monitored under the conditions detailed below as per O-RAN.WG4.CONF.0-R003-v09.00 Sections 3.3.5 and 3.3.6. No timing performance requirements are specified for the functional tests.

The functional tests apply to deployment configurations LLS-C1, LLS-C2, LLS-C3, and LLS-C4.

6.1. Functional Test: O-DU Synchronized from ITU-T G.8275.1 Profile PRTC/T-GM

The PTP and (if used) SyncE input conditions to the O-DU are changed by the user in the order shown in Table 3.3.5-1 of the O-RAN.WG4.CONF document, and the O-DU status is compared to the expected results defined in Tables 3.3.5-2 and 3.3.5-3 of that document. These tables are reproduced as Table 3, Table 4 and Table 5 respectively in this section.

Step	PTP Status	SyncE Status (if applicable): SSM
1	Startup: no clockclass	Startup: no SSM/QL
2	Nominal clockclass=6	Nominal QL= (see Note 1)
3	Degraded clockclass but within the O-DU's configured accepted range.	Nominal QL= (see Note 1)
4	Degraded clockclass outside the O-DU's configured accepted range.	Nominal QL= (see Note 1)
5	Degraded clockclass outside the O-DU's configured accepted range.	Degraded QL outside the O-DU's configured accepted range
6	Nominal clockclass=6	Nominal QL= (see Note 1)
7	Nominal clockclass=6	Degraded QL but within the O-DU's configured accepted range
8	Nominal clockclass=6	Degraded QL outside the O-DU's configured accepted range
9	Nominal clockclass=6	Nominal QL= (see Note 1)
10	S-plane lost; no message	S-plane lost; no message

Table 3: O-DU C1/C2/C3/C4 Functional Conformance Test Steps

Note 1: For SyncE, Nominal QL is what is determined as the best acceptable configured value by the O-DU.

Testing is performed in three phases:

- 1. Startup initially, Paragon-neo and the O-DU are connected as per Section 4 with no generation active.
- 2. **Nominal** Paragon-neo PTP emulation is started, along with ESMC generation if required, with the PTP Clock Class (and SyncE QL value, if applicable) configured such that the O-DU will lock to those inputs.
- 3. Degraded Paragon-neo is then configured in turn to create two different degraded input conditions for the O-DU:
 - a. In the first degradation level, Paragon-neo is configured to send PTP Clock Class (and SyncE QL, if applicable) values within the O-DU's configured accepted limits.
 - b. In the second degradation, the PTP Clock Class (and SyncE QL, if applicable) values sent by Paragon-neo are outside the O-DU's configured accepted limits.

6.1.1. Test Procedure

- 1. Confirm the Paragon-neo is configured as per Section 5, including the PTP and SyncE QL configurations.
- Confirm that there is no active generation. Power the O-DU off then back on again, this is the *Startup* phase. The pass/fail criteria for this phase are detailed in the next section.
- 3. Navigate to the O-RAN Conformance Test app. From the Test: drop-down select O-DU Ideal.

O-RAN Conform	ance Test		
Test:	O-RU Ideal	~	
Settling Time:	O-RU O-RU Ideal O-RU PTP LLS-C1 (Sines)		
Generation:	O-RU PTP LLS-C2 (Sines)	Measurement:	
✓ PTP ✓ ESMC	O-RU SyncE LLS-C2 & LLS-C3 (EEC) O-RU SyncE LLS-C2 & LLS-C3 (EEC) O-DU	✓ PTP ✓ 1pps Time i	Error
	O-DU Ideal O-DU PTP 6.8271.1 Ref point C (Noise) O-DU PTP Ref point C (Sines) O-DU PTP Ref point B (Sines) O-DU SyncE (EEC)	SyncE Wan	ider PF/
Elapsed Time:	O-DU SyncE (eEEC) Elapsed Time:	ig: N/A 00d 00h 00m	00s

- 4. From the Generation section of the conformance test app, press Generate. This starts PTP and ESMC message generation.
- 5. If the O-DU outputs SyncE, in the Measurement section check the SyncE Wander checkbox to enable SyncE measurement.

O-RAN Conform	nance Test			
Test:	O-RU Ideal	~		
Settling Time:	0 seconds	Apply Undo		
Generation: ☑ PTP ☑ ESMC	снеск	Stimulus: PTP Noise Pattern PTP Noise Table SyncE Wander Table SyncE Wander Offset	Measurement: PTP 1pps Time Error SyncE Wander	START PF/
Elapsed Time	: 00d 00h 00m 50s	Estimated Time Remaining Elapsed Time:	y: N/A 00d 00h 00m 00s	ØT

- 6. In the **Stimulus/Measurement** section, press **Start** to begin measuring the PTP and (if configured) SyncE outputs from the O-DU.
- 7. Each of the required PTP Clock Class (and, if used SyncE QL) value changes should be manually implemented in the order shown in Table 3 to perform the **Nominal** and **Degraded** state testing.
 - The procedures to change the PTP Clock Class (and, if used) SyncE QL are detailed in section 6.2.
 - The pass/fail criteria for each step are detailed in the next section.

If required, **Stop** the measurement after each step to enable analysis of the PTP Clock Class and SyncE QL values being output from the O-DU. In this case, the measurement should be started again after the O-DU input conditions have been changed.

6.1.2. Results Interpretation – Pass/Fail Criteria

For each of the phases, the behaviour and status of the O-DU should be monitored either by external M-plane observation or on the O-DU console.

The PTP Clock Class and the and SyncE QL output by the O-DU during each step are to be monitored in the CAT and PFV applications – this is detailed in section 6.4.

Table 4 below shows the expected results for an O-DU using PTP only, and Table 5 the results for an O-DU using both PTP and SyncE.

		PTP	Input Paramete	ers	PTP	/SyncE Outp	ut Parameters	ers and an approximate an approximate<	
Step O-DU PTP Status		sync -state	ptp sync-source-status	ptp clock-class	ptp master sync-source-status	ptp master clock-class	synce master sync-source-status	synce master quality-level	
1	Startup	FREERUN	NOT_ USABLE	248 or 255	NOT_ USABLE	248	NOT_ USABLE	Note 1	
2	Nominal	LOCKED	IN_USE	Rcvd Value	IN_USE	Rcvd Value	IN_USE	PRC	
3	Degraded, within range	LOCKED	IN_USE	Rcvd Value	IN_USE	Rcvd Value	IN_USE	Note 1	
4 - 5	Degraded, outside range.	HOLD OVER (Note 2) NOT_ then USABLE RCV FREERUN		Rcvd Value	IN_USE (Note 2) then NOT_ USABLE	Notes 1, 4	IN_USE (Note 2) then NOT_ USABLE	Note 1	
6 - 9	Nominal	LOCKED	IN_USE	Rcvd Value	IN_USE	Rcvd Value	IN_USE	PRC	
10	None (disconnected)	HOLD OVER (Note 2) then FREERUN	NOT_ IN_USE	Notes 1, 4	IN_USE (Note 2) then NOT_ USABLE	Notes 1, 4	IN_USE (Note 2) then NOT_ USABLE	Note 1	

Table 4: O-DU C1/C2/C3/C4 Functional Conformance Test Results without SyncE

Note 1: This is not specified by CUS-Plane and is implementation dependent.

Note 2: After HOLDOVER (either assisted by SyncE or relying on local oscillator) expires, then the O-DU goes to FREERUN. In CUS-Plane specification [2] the FREERUN state is defined to occur at start up prior to O-DU acquiring LOCK, and it also occurs when O-DU is in HOLDOVER and the reference is no longer within specification.

Note 3: in case of local failure inside the O-DU.

Note 4: as per ITU-T G.8275.1 [5], degraded clockclass values in holdover may be either, (a) 7, then 140 or150 or 160, for an O-DU acting as a Grandmaster clock, or (b) 135, then 165 for an O-DU behaving as a Boundary clock.

* 'Received value' indicates that the output value from the O-DU is the same as that it receives, except for in the *Startup* phase where the output value shall be the O-DU default value as there is no input.

		I	PTP/SyncE lr	nput Para	meters		PTP/SyncE Output Paramet			ters
Step	O-DU PTP and SyncE Status	sync -state	ptp sync-source-status	ptp clock-class	synce sync-source-status	synce quality-level	ptp master sync-source- status	ptp master clock-class	synce master sync- source-status	synce master quality- level
1	Startup	FREERUN	NOT_ USABLE	248 or 255	NOT_ USABLE	Note 1	NOT_ USABLE	248	NOT_ USABLE	Note 1
2	PTP: Nominal SyncE: Nominal	LOCKED	IN_USE	Rcvd Value	IN_USE or USABLE	Rcvd Value	IN_USE	Rcvd Value	IN_USE	Rcvd Value
З	PTP: Degraded, in range SyncE: Nominal	LOCKED	IN_USE	Rcvd Value	IN_USE or USABLE	Rcvd Value	IN_USE	Rcvd Value	IN_USE	Rcvd Value
4	PTP: Degraded, outside range. SyncE: Nominal	HOLD OVER (Note 2) then FREERUN	NOT_ USABLE	Rcvd Value	IN_USE	Rcvd Value	IN_USE (Note 2) then NOT_ USABLE	Notes 1, 4	IN_USE then NOT_ USABLE	Rcvd Value
5	PTP: Degraded, outside range. SyncE: Degraded, outside range.	HOLD OVER (Note 2) then FREERUN	NOT_ USABLE	Rcvd Value	NOT_ USABLE	Rcvd Value	IN_USE (Note 2) then NOT_ USABLE	Notes 1, 4	IN_USE then NOT_ USABLE	Rcvd Value
6	PTP: Nominal SyncE: Nominal	LOCKED	IN_USE	Rcvd Value	IN_USE or USABLE	Rcvd Value	IN_USE	Rcvd Value	IN_USE	Rcvd Value
7	PTP: Nominal SyncE: Degraded, in range.	LOCKED	IN_USE	Rcvd Value	IN_USE or USABLE	Rcvd Value	IN_USE	Rcvd Value	IN_USE	Rcvd Value
8	PTP: Nominal SyncE: Degraded, outside range.	Implementat ion Specific (Note 5)	IN_USE	Rcvd Value	NOT_ USABLE	Note 1	IN_USE or (Note 2) NOT_ USABLE	Rcvd Value	Note 1	Note 1
9	PTP: Nominal SyncE: Nominal	LOCKED	IN_USE	Rcvd Value	IN_USE or USABLE	Rcvd Value	IN_USE	Rcvd Value	IN_USE	Rcvd Value
10	PTP: None (disconnected) SyncE: None (disconnected)	HOLD OVER (Note 2) then FREERUN	NOT_ IN_USE	Notes 1, 4	NOT_ IN_USE	Note 1	IN_USE (Note 2) then NOT_ USABLE	Notes 1, 4	IN_USE then NOT_ USABLE	Note 1

Table 5: O-DU C1/C2/C3/C4 Functional Conformance Test Results with SyncE

Note 1: This is not specified by CUS-Plane and is implementation dependent.

Note 2: After HOLDOVER (either assisted by SyncE or relying on local oscillator) expires, then the O-DU goes to FREERUN. In CUS-Plane specification [2] the FREERUN state is defined to occur at start up prior to O-DU acquiring LOCK, and it also occurs when O-DU is in HOLDOVER and the reference is no longer within specification.

Note 3: in case of local failure inside the O-DU.

Note 4: As per ITU-T G.8275.1 [5], degraded clockclass values in holdover may be either, (a) 7, then 140 or150 or 160, for an O-DU acting as a Grandmaster clock, or (b) 135, then 165 for an O-DU behaving as a Boundary clock.
 Note 5: Depending on O-DU implementation the Sync-state may be LOCKED or "HOLDOVER (Note 2) then FREERUN."

* 'Received value' indicates that the output value from the O-DU is the same as that it receives, except for in the *Startup* phase where the output value shall be the O-DU default value as there is no input.

6.2. Functional Test: O-DU Synchronized from Embedded or Local non-PTP PRTC

The GNSS-RF and 1PPS+ToD input conditions to the O-DU are changed in the order shown in Table 3.3.6-1 of the O-RAN.WG4.CONF document, and the O-DU status is compared to the expected results defined in Tables 3.3.6-2 of that document. These tables are reproduced as Table 6 and Table 7 respectively in this section.

Providing controlled degraded GNSS RF input to the O-DU requires a GNSS simulator. Further information about using a GNSS simulator to test timing devices can be found in the Calnex Test Guide: *CX3016 Paragon-neo PRTC Test Guide*.

Step	GNSS RF or PRTC output Status				
1	Startup Status (and GNSS Acquiring Mode if implemented) - Note 1				
2	Nominal				
З	Degraded				
4	Nominal				
5	Failed (no signal)				
Note 1: After prog	Note 1: After a power cycle it may take some time for GNSS receiver or PRTC to complete self-survey and progress to Nominal mode.				

Table 6: O-DU C1/C2/C3/C4 Functional Conformance Test Steps

Testing is performed in three phases:

- 1. Startup initially, Paragon-neo and the O-DU are connected as per Section 4 with no generation active.
- 2. **Nominal** The GNSS simulator or Paragon-neo PRTC emulation (1PPS+ToD Test Out) is started and configured such that the O-DU will lock to those inputs.
- 3. **Degraded** The GNSS simulator or Paragon-neo PRTC emulation (1PPS+ToD Test Out) is then configured in turn to create two different degraded input conditions for the O-DU:
 - a. In the first degradation level the GNSS simulator output or Paragon-neo PRTC emulation values are within the O-DU's configured accepted limits.
 - b. In the second degradation, the GNSS simulator output or Paragon-neo PRTC emulation values are within the O-DU's configured accepted limits.

6.2.1. Test Procedure

This procedure details the steps to perform this test by configuring the Paragon-neo to emulate a PRTC providing a 1PPS+ToD input to the O-DU. In the case that the O-DU has a GNSS RF input, information see Calnex Test Guide: *CX3016 Paragon-neo PRTC Test Guide* for further information.

- 1. Confirm the Paragon-neo is configured as per Section 5.
- 2. Confirm that there is no active generation. Power the O-DU off then back on again, this is the *Startup* phase.

The pass/fail criteria for this phase are detailed in the next section.

3. Navigate to the O-RAN Conformance Test app. From the Test: drop-down select O-DU Ideal.

O-RAN Conform	ance Test		
Test:	O-RU Ideal	~	
Settling Time:	O-RU O-RU Ideal O-RU PTP LLS-C1 (Sines)		
Generation:	O-RU PTP LLS-C2 (Sines) O-RU SyncE LLS-C1	Measurement:	
🗹 РТР	O-RU SyncE LLS-C2 & LLS-C3 (EEC)	🗹 РТР	
🗹 ESMC	O-RU SyncE LLS-C2 & LLS-C3 (eEEC) O-DU	1pps Time Error	
	O-DU Ideal O-DU PTP G.8271.1 Ref point C (Noise) O-DU PTP Ref point C (Sines)	SyncE Wander	PF/
Elapsed Time:	O-DU SyncE (EEC) O-DU SyncE (EEC) O-DU SyncE (eEEC) Elapsed Time:	ıg: N/A 00d 00h 00m 00s	Z IT

4. Navigate to the **Time of Day Generation** app. From the **Format:** select the message type that the O-DU is configured to receive.



5. Expand the Message Settings and set the desired values to enable the O-DU to lock to the 1PPS+ToD signal.

Message parameters are changed by making selections using the drop-down menus and checkboxes. If a setting has been changed it will be indicated in yellow. Click **Apply** to apply the settings.



6. From the **Time of Day Generation** app, press **Generate**.

Time of Day Generation	
GENERATE Elapsed Time 00d 00h 33m 15s	✓ Event Format: G.8271 ✓ Announce ✓ GNSS

7. From the **Generation** section of the **Conformance Test** app, press **Generate**.

This starts PTP and ESMC message generation and allows measurement of the O-DU PTP and SyncE outputs, however during this entire test the O-DU must not use PTP or SyncE references; the reference to the O-DU must be 1PPS+ToD only.

8. If the O-DU outputs SyncE, in the Measurement section, check the SyncE Wander checkbox to enable SyncE measurement.

O-RAN Conform	ance Test			
Test:	O-RU Ideal	~		
Settling Time:	0 seconds	Apply Undo		
Generation:		Stimulus:	Measurement:	\bigcirc
🖉 РТР	STOP	PTP Noise Pattern	🗹 РТР	START
SMC		PTP Noise Table	1pps Time Error	
	\sim	SyncE Wander Table	SyncE Wander	DEZ
	CHECK	SyncE Wander Offset		
		Estimated Time Remaining	: N/A	
Elapsed Time:	: 00d 00h 00m 50s	Elapsed Time:	00d 00h 00m 00s	

- In the Stimulus/Measurement section of the O-RAN Conformance App, press Start to begin measuring the PTP and (if used) SyncE outputs from the O-DU.
- 10. Parameter value changes should be manually implemented to the **Message Settings** in the Paragon-neo **Time of Day Generation** app in the order shown in Table 6 to perform the **Nominal** and **Degraded** state testing.
 - The procedure to change these values are detailed in section 6.3.3
 - The pass/fail criteria for each step are detailed in the next section.

If required, **Stop** the measurement after each step to enable analysis of the PTP Clock Class and SyncE QL values being output from the O-DU. In this case, the measurement should be started again after the O-DU input conditions have been changed.

6.2.2. Results Interpretation – Pass/Fail Criteria

For each of the phases, the behaviour and status of the O-DU should be monitored either by external M-plane observation or on the O-DU console.

The PTP Clock Class and the and SyncE QL output by the O-DU during each step are to be monitored in the CAT and PFV applications – this is detailed in section 6.4.

Table 7 below shows the expected results.

		GNS	SS Input Paramet	ers	PTP/SyncE Output Parameters						
Step O-DU GNSS, Status		sync -state	sync -state gnss sync-source-status		ptp master sync-source- status	ptp master clock-class	synce master sync-source-status	synce master quality-level			
1	Startup	FREERUN	USABLE	ACQUIRING- SYNC	NOT_ USABLE	248	NOT_ USABLE	Note 1			
2	Nominal	LOCKED	IN_USE	SYNCH- RONIZED	IN_USE	6	IN_USE	PRC			
3	Degraded	HOLD OVER (Note 2) then FREERUN	NOT_ IN_USE then NOT_ USABLE	SYNCH- RONIZED	NOT_ IN_USE (Note 2) then NOT_ USABLE	(Notes 1, 3)	NOT_ IN_USE (Note 2) then NOT_ USABLE	Note 1			
4	Nominal	LOCKED	IN_USE	SYNCH- RONIZED	IN_USE	6	IN_USE	PRC			
5	Failed (no signal)	HOLD OVER (Note 2) then FREERUN	NOT_IN_USE	ANTENNA- DISCON- NECTED	NOT_IN_USE (Note (Note 2) then 1, 3 NOT_USABLE		NOT_ IN_USE (Note 2) then NOT_ USABLE	Note 1			

Table 7: O-DU C1/C2/C3/C4 Functional Conformance Test Results with GNSS Reference

Note 1: This is not specified by CUS-Plane and is implementation dependent.

Note 2: After HOLDOVER (relying on local oscillator) expires, then O-DU goes to FREERUN. In CUS-Plane specification the FREERUN state is defined to occur at start up prior to O-DU acquiring LOCK, and it also occurs when O-DU is in HOLDOVER and the reference is no longer within specification.

Note 3: As per ITU-T G.8275.1[5], degraded clockclass values in holdover may be 7, then 140 or150 or 160, for an O-DU acting as a Grandmaster clock.

* 'Received value' indicates that the output value from the O-DU is the same as that it receives, except for in the *Startup* phase where the output value shall be the O-DU default value as there is no input.

6.3. Changing the Input Conditions

The input conditions to the O-DU are changed using the procedures in the sections below.

6.3.1. Changing the PTP Clock Class

The PTP Clock Class is carried in the Announce message from the emulated PTP timeTransmitter, and so can be changed in the **timeTransmitter Configuration** panel. Click the **TT Config** button in the **PTP Emulation** app to show the configuration options, then the **Announce** tab to view the **Clock Class** field:

Test Mode:	Test Mode: Boundary Clock						
PTP Profile:	G.8275.1 Phase Profile	~					
PTP Standard:	IEEE 1588-2008	~					
	T Test TR Config Config D.U.T.						



The value can be changed while emulation is running by entering a new value in the field. This will cause the field to go yellow as **Apply** must be clicked to send the setting to the instrument.

time Transmitter Configuration							Apply	Undo	
General VLAN Tags	Messaging	Unicast		Announce	TLVs				
Priority 1:	128		PTP	Leap 59					
Priority 2:	Priority 2: 128				PTP Leap 61				
Clock Class:	7		🗸 РТР	Timescale					
Clock Accuracy:	100 ns	~	✓ Current UTC Offset Valid						
Time Source:	Internal	~	✓ Time Traceable						
Current UTC Offset (s): 37			✓ Frequency Traceable						
Steps Removed:	0								
Offset Scaled Log Variance:	ff:ff								

Once applied, the new value will be carried in the Announce message and its effect on the O-DU observed.

6.3.2. Changing the SyncE Quality Level

SyncE Quality Level is carried in the SSM Code field of the ESMC message from the emulated SyncE clock, and so can be changed by modifying the **SSM Code** in the **ESMC Generation (Port 1)** panel.

ESMC Generation (P	ort1)	
STOP	Enhanced SSM Network Option: Option 1 SSM Code: QL-PRC Event Flag QL-SSU-A OL-SSU-B QL-EC1/SEC QL-EC1/SEC QL-DNU	Partial Chain Mixed EEC/eEEC Cascaded eEECs: 0 Cascaded EECs: 0 Cascaded EECs: 0 Undo Undo Inter-packet Gap: 1000 ms MAC Address: 0:0:00:00:00:00:2b

The value can be changed while emulation is running.

Once applied, the new value will be carried in the ESMC messages and its effect on the O-DU observed.

6.3.3. Changing the 1PPS+ToD status

The status of the 1PPS+ToD is carried in the Time of Day message. Paragon-neo supports CCSA, NMEA and G.8271 message formats. The parameters and values to indicate status are different for each message format; knowledge of how the O-DU will interpret each status indicator will determine the specific setting to achieve the desired effect.

To change the status indicators, navigate to the Time of Day Generation app and expand Message Settings.

Message parameters are changed by selecting values and checking the checkboxes. If a setting has been changed it will be indicated in yellow. Clicking **Apply** will immediately apply the values to the output Time of Day message.

Values can be changed while generation is running.

Time of Day Generation			
STOP	Elapsed Time 00d 00h 00m 07s	Format: 6.8271 V	 ✓ Event ✓ Announce ✓ GNSS
▲ Message Settings			Apply Undo
Use settings from PTP	Emulation configuration		
Event Annou	nce GNSS		
Time Source Type:	GPS 🗸	0	
Time Source Status:	No Fix 👻	0	
Alarm Status Monitor:	Antenna Open	Leap Second Pending	
	Antenna Shorted	in Test Mode	
	✓ Not Tracking Satellites	✓ Gnss Solution Is Uncertain	
	Survey In Progress	Almanac Not Complete	
	No Stored Position	Pps Was Generated	

6.4. Using CAT and PFV to Monitor the O-DU Output

The procedure below shows how to use the CAT and PFV applications to monitor the PTP Clock Class and SyncE QL values being output by the O-DU.

6.4.1. Monitoring O-DU PTP Clock Class using PFV

1. In the **O-RAN Conformance Test App**, launch the PFV application a new browser window by clicking the associated button:



2. In the PFV application, use the horizontal scroll bar to navigate to the gmClkClass column.

րբ	7								Files	PTP	ToD Repo	ort System	Help
▲! ▼! Rule	set File: G.82	75.1_Phase_Profile.xm	hl	View Rules					Selecter	d packet #:			Go To
			Decoded						Announce [Body Fields			
Direction	Packet #	Arrival Time	PTP Version	Inter Message Time	Message Type		curUtcOffset	gmPrior1	gmClkClass	gmClkAcc	gmClkOslv	gmTimeSource	
🚞 Þ 🛛	451	8.000090726250	2.0	0.062500044750	DEL-RESP	1							
	452		2.0	0.062500044750	SYNC								1 🗒
- 2	453		2.0	0.062499840000	DEL-REQ								1 🔛
	454		2.0	0.062499840000	DEL-RESP								×
	455		2.0	0.062500044750	SYNC								1
	456		2.0	0.125000089750	ANNOUNCE	gmClkOslv=0xffff gmPrior				0x21	Oxffff	0xa0	1
- 2	457		2.0	0.062500044750	DEL-REQ								1
	458		2.0	0.062500045000	DEL-RESP								1
	459		2.0	0.062500044750	SYNC								1
- 2	460		2.0	0.062500045000	DEL-REQ								1
	461		2.0	0.062500044750	DEL-RESP								1
	462		2.0	0.062500045000	SYNC								1
	463		2.0	0.124999884750	ANNOUNCE	gmClkOslv=0xffff gmPrior				0x21	Oxffff	0xa0	1
- 2	464		2.0	0.062500044750	DEL-REQ								1
	465		2.0	0.062500044750	DEL-RESP								1
	466		2.0	0.062499840000	SYNC								1
- 2	467		2.0	0.062500044750	DEL-REQ								1
	468			0.062500044750	DEL-RESP								1
	469		2.0	0.062500044750	SYNC								1
🛁 Þ 🛛	470		2.0	0.125000089500	ANNOUNCE	gmClkOslv=0xffff gmPrior				0x21	Oxffff	0xa0	1
- 2	471		2.0	0.062499840000	DEL-REQ								1
🛁 Þ 🛛	472			0.062499840000	DEL-RESP								1
🛁 Þ 🛛	473		2.0	0.062500045000	SYNC								1
- 2	474		2.0	0.062500044750	DEL-REQ								1
🛁 Þ 🛛	475		2.0	0.062500044750	DEL-RESP								
-							<u> </u>	_		_	_		
					Messan	e: Pate (men/sec)	er-messarie Inte	nal	Count				
					messag	c. Rate (msg/sec)	er-message me	····				PASS	
					SYNC	16.00 FOLLON	V-UP	TX/F	хт 😑 🗴	RX	Total Pa	ss Rate: 100.00%	6
Cali					DEL-R	EQ 16.00 DEL-RE	SP 16.0	00			Total Counts		
Call	IEX				PDC		CSP						
					PDEL-	NEQ PDEL-R	Eor	FDEL-RI	ESP-FOP		Packets		476
					ANNO	UNCE 8.00 SIGNAL	ING	MANAG	EMENT		Errored Pack	tets	0

3. The value in the gmClkClass column shows the Clock Class being output by the O-DU in the associated Announce Message.

6.4.2. Monitoring O-DU SyncE QL Values using CAT

1. In the **O-RAN Conformance Test App**, launch the CAT application a new browser window by clicking the associated button:

O-RAN Conform	ance Test			
Test:	O-DU Ideal	~		
Settling Time:	0 seconds	Apply Undo		
Generation:	блеск	Stimulus: PTP Noise Pattern PTP Noise Table SyncE Wander Table SyncE Wander Offset Estimated Time Remaining	Measurement: PTP Jpps Time Error SyncE Wander N/A	STOP PF/
Elapsed Time:	: 00d 00h 00m 10s	Elapsed Time:	00d 00h 00m 08s	

2. In the CAT application, click on the TIE/ESMC tab to open those metrics.

The ESMC Quality Rx (Port 2) plot shows the SyncE QL values being output by the O-DU during the capture:



3. Double-clicking on the plot area will expand into a single-view where a table of the plotted values is also displayed:

Time Error	Time Error (Filt	ered) Avg Time Err	or (cTE)	Dynam	Dynamic Time Error TIE / ESMC			Port Events		$\langle \rangle$
ESMC OU	ality: Tx (Port 2)	/ 👞 ESMC Quality: R	r (Port 2)							
QL-STU/U	NK -		(1 012)							
QL-ePR	TC -									ŝ
QL-P	RS -									
QL-eP QL-P	RC - ESMC Quali	ity: Rx (Port 2)							1	€
QL-IN QL-SSU-A/T	IV3 - NC -									Q
≩ QL-IN	IV5 -									-
	ST2 -									
	J-B – IV9 –									
QL-eE	EC -									
QL-EEC1/S	EC -								.	_
QL-S QL-S1	мс – ГЗЕ –									
QL-PR QL-DNU/D	OV - US - ESMC Qual	the Ty (Doct 2)								
No ESMC D									•••	-
	U	20 40	60	Elaps	80 sed Time [s]	100	120	140	161	J
					ESMC Qu	uality				2
ESMC Event #	Elapsed Time (s)	Date / Time		Tv			Dv			*
										^
0	0.927	2023-04-20 20:47:19	No E	SMC Data	Yet	QL	-PRC (0x2)			×
1	148.963	2023-04-20 20:49:47	No E	SMC Data	Yet	QL-EEC	C1/SEC (0xb) (E)			×
	149.975	2023-04-20 20:49:48	No E	SMC Data	Yet	QL-EE	EC1/SEC (0xb)			
3	156.965	2023-04-20 20:49:55	No E	SMC Data	Yet	QL-DN	U/DUS (0xf) (E)			
	157.966	2023-04-20 20:49:56	No E	SMC Data	Yet	QL-D	NU/DUS (0xf)			
	163.436	2023-04-20 20:50:02	No E	SMC Data	Yet	QL-D	NU/DUS (0xf)			

7. O-DU CONF 3.3.7 Performance Test

This test is defined in document O-RAN.WG4.CONF.0-R003-v09.00, O-RAN Working Group 4 (Fronthaul Working Group) Conformance Test Specification clause 3.3.7.

This test validates that the O-DU is synchronizing to Paragon-neo providing it PTP and, if required, SyncE. Frequency and time error generated by the O-DU must be within the specified limits.

The performance tests are mandatory for O-DU's that support LLS-C1, LLS-C2 deployment configurations and do not only derive their timing from an embedded PRTC. The tests are optional for O-DU's that only support LLS-C3 and LLS-C4 deployment configurations.

The timing errors generated for PTP and SyncE could be applied either simultaneously or in sequence. There are benefits to either: in sequence allows isolation of device performance characteristics based on stimulus type; simultaneously, represents a more realistic option to verify expected performance in a real network, therefore this section contains instructions for testing both separately and simultaneously.

7.1. Test Description

This section provides information about the test requirements and the applicable timing signal types.

7.1.1. O-DU Performance Requirements

The overall synchronization performance of an O-DU is defined in the *O-RAN Working Group 4 (Open Fronthaul Interfaces WG) Control, User and Synchronisation Plane Specification* document *O-RAN.WG4.CUS.0-R003-v13.00,* Section 11, with additional information in Annex H. The CUS specification defines key synchronization parameters that must be met:

Table 8: CUS Key Synchronization Parameters

Metric	Limit	Reference
Network Time Error Budget (MaxITE∟)	1.420μs (LLS-C1) 1.325μs (LLS-C2) 1.5 μs (LLS-C3 & LLS-C4)	Table 11.3.2.1-1
Maximum Absolute Frequency Error (MaxIFEI)	15ppb (Class A O-DU) 5ppb (Class B O-DU)	Table 11.3.2.1-1

O-RAN.WG4.CONF clause 3.3.3 defines tests that validate the conformance to the CUS specifications above by measuring performance of the O-DU outputs in different scenarios.

7.1.2. Test Scenarios

Two scenarios are tested, Ideal Operation and Normal Operation:

- 1. Ideal Operation: The time source provides "ideal" O-DU synchronization input with no implicitly added dynamic or constant time error. This applies when testing with either a local or remote time source.
- 2. Normal Operation: The time source provides an input stimulus with some added noise that is "within normal operating limits." O-DU inputs as specified in CUS-Plane Specification.

The performance specification of an O-DU for both scenarios is:

- a. Maximum 0.1 Hz low pass filtered frequency error for LLS-C1 and LLS-C2 deployment configurations:
 - ±15 ppb for class A O-DU
 - ±5 ppb for class B O-DU
- b. Maximum 0.1 Hz low pass filtered time error:
 - ±1420 ns for LLS-C1

- ±1325 ns for LLS-C2.
- ±1500 ns for LLS-C3 and LLS-C4

The thermal conditions are not defined by O-RAN. The tests are intended to be run at a constant temperature, but the specific temperature conditions to be used are to be decided by the device vendor.

7.1.3. Timing Signal Types

O-RAN.WG4.CONF clause 3.3.7 states: "For LLS-C1 and LLS-C2 configuration, the test is set up to measure frequency and time error at one of the Ethernet master fronthaul ports of the O-DU. For LLS-C3 and LLS-C4 configuration, the test is configured to measure time error on a measurement port of the O-DU, typically a 1PPS signal if available or an unused Ethernet port."

Regarding PLFS (typically SyncE) output from the O-DU, O-RAN.WG4.CUS clause 11.2.3, for LLS C1 deployments states: "*in the specific case where O-RU does not make use of PLFS, in which case PLFS emission shall be optional for the O-DU*". Therefore, SyncE measurement is optional in this specific case.

The above means that depending on the specific deployment configuration, functionality of the O-DU, and the SyncE requirement of the O-RU, performance measurements must be made on the PTP, and optionally the SyncE and/or 1PPS outputs from the O-DU.

O-RAN.WG4.CUS clause 11.2.3 states: "...an DU or O-RU end application is not required to use a PLFS to achieve clock (frequency) synchronization. They can use PTP alone to achieve both frequency and phase/time synchronization." Configuration of Paragon-neo for testing should, therefore, match the requirements of the O-DU regarding provision of a SyncE input.

7.2. Performance Test: PTP Operation

To test the "Ideal Operation" scenario, no impairments are applied to the input of the O-DU.

"Normal Operation" can be emulated in two ways. The first method is by applying a pattern of sine wave time errors to the PTP input of the O-DU. These are defined in Table 3.3.7-1 of the O-RAN.WG4.CONF specification which is reproduced below for reference. Note that this table has been updated in O-RAN.WG4.CONF.0-R003-v09.00 to make the time errors slightly larger (closer to the ITU-T G.8271.1 MTIE limits), the values from v08.00 and earlier are shown below and they are the values currently used in the built-in Paragon-neo O-RAN PTP impairment patterns, see Section 7.5.1 of this document for the procedure to test using the values specified in v.09.00.

	At Referen	ce Point C	At Referen		
Frequency [Hz]	dTE Amplitude [ns]	Constant Time Error [ns]	dTE Amplitude [ns]	Constant Time Error [ns]	Test duration [s]
0.003362	190	910	25	75	595 (2 periods)
0.010	155	945	17	83	500 (5 periods)
0.100	140	960	12	88	50 (5 periods)

Table 9: Time error limits for O-DU input

A second method is also defined in O-RAN.WG4.CONF: "An alternative and more representative method for reference point C is to apply a noise pattern that meets the network limit mask defined in ITU-T G.8271.1, Table 7-1/Figure 7-2. ... The advantage of this is that it is more representative of real network conditions and transients, and therefore a more effective test of the O-DU under emulated network conditions." This noise pattern is integrated into Paragon-neo and Calnex recommend this method as the measurement results provide a better indication of the expected O-DU performance in deployment.

7.2.1. Procedure – PTP Input Test

The appropriate test stimulus is automatically applied depending on the selected test within the O-RAN Conformance Test app.

- 1. Navigate to the **O-RAN Conformance Test** app, from the **Test:** drop-down select type of test required:
 - O-DU Ideal (no impairment pattern).
 - O-DU PTP G.8271.1 Ref point C (Noise) to apply the representative network noise pattern specified in O-RAN.WG4.CONF.
 - O-DU PTP Ref point C (sines) or O-DU PTP Ref point B (sines) to apply the sine wave patterns specified in O-RAN.WG4.CONF.



2. The **Settling Time** parameter specifies the amount of time between applying PTP stimulus and starting measurement, allowing the device to settle after instantaneous changes in cTE that are inherent in some of the impairment patterns and are applied when the conformance test is started. There is no specification for the maximum settling time however it can be configured to a maximum of 620s (10m 20s).

Device conformance testing is not affected by setting this because the settling time is prior to the point in the sines impairment patterns that the specific conformance tones start. The network noise impairment patterns are of a duration and have characteristics such that an allowance for device settling will not affect the test results.

If required, enter the desired settling time for the O-DU and click Apply.

O-RAN Conformance Test						
Test:	O-DU PTP G.8271.1 Ref po	O-DU PTP G.8271.1 Ref point C (Noise)				
Settling Time:	300 seconds	Apply 🕕	Undo			

3. In the **Measurement** section, click the **SyncE Wander** and/or **1pps Time Error** checkboxes to enable or disable SyncE or 1PPS measurements depending on the output types generated by the O-DU.

O-RAN Conform	ance Test			
Test:	O-DU PTP G.8271.1 Ref	point C (Noise) 🗸 🗸		
Settling Time:	100 seconds	Apply Undo		
Generation:	\frown	Stimulus:	Measurement:	
🗹 РТР	GENERATE	PTP Noise Pattern	✓ РТР	(start)
SMC ESMC		PTP Noise Table	1pps Time Error	
	\sim	SyncE Wander Table	🗹 SyncE Wander	
	CHECK	SyncE Wander Offset		
		Estimated Time Remaining	j: N/A	
Elapsed Time:	00d 00h 00m 00s	Elapsed Time:	00d 00h 00m 00s	

- 4. If the O-DU uses SyncE, in the **ESMC Generation (Port 1)** app confirm that the appropriate settings have been configured to enable the O-DU to use SyncE as a reference as detailed in section 5.4.
- 5. From the Generation section of the conformance test app, press Generate. This starts PTP and ESMC message generation allowing the O-DU to stabilize. Pressing Check will run a simultaneous timing capture and the CAT application will open in a new browser tab this can be used to check current timing performance prior to starting the test.
 - Wait for the measured output(s) of the O-DU moving from a ramp to stable condition to indicate lock has been achieved.
 - If the O-DU does not achieve lock, then perform troubleshooting of the configuration of the O-DU and Paragon-neo to determine the root cause.

6. Once the O-DU is stable, in the **Stimulus/Measurement** section, press **Start** to run the measurement.

The **O-DU Ideal measurement** should be run for at least 1000s. The tests that apply stimulus to the PTP input to the O-DU must be run until at least the *Estimated Time Remaining* has counted down to zero, the 'Sines' pattern are approximately 3000s and the 'Noise' pattern is approximately 33,000s.

O-RAN Co	nformance Te	st			
Test:	O-DU	PTP Ref point C (Si	ines) 🗸		
Settling 1	lime: 100	seconds	Apply Undo		
Generat ☑ PTP ☑ ESW	ion: IC	снеск	Stimulus: PTP Noise Pattern PTP Noise Table SyncE Wander Table SyncE Wander Offset	Measurement: PTP 1pps Time Error SyncE Wander	STOP PF/
Elapsed	Time: 00d 00	h 00m 20s	Estimated Time Remaining Elapsed Time:	: 00d 00h 49m 45s 00d 00h 00m 17s	

7. You can observe the progress of any applied stimulus by navigating to the **Status** tab of the **PTP Impairments (Port 1)** app; the current position within the pattern is indicated by the red bar.



7.2.2. Results Analysis

1. From the **O-RAN Conformance Test** app, click on **CAT.** The Calnex Analysis Tool will open in a new browser tab displaying the default metrics.



2. The **Test Environment** function automatically configures the displayed metrics, masks, and thresholds to a range of preset values such as those required for testing compliance to device or network standards.

Select the appropriate **Test Environment** for the current test and O-DU output type. This step and the following steps should be repeated for each output type: PTP and/or 1PPS.



3. Navigate to the available metrics for the Test Environment by using the tabs at the top of the window.



4. The O-DU performance meets requirements when the output is within the applied masks and thresholds. This is indicated in the top-right area of the CAT display.



Note: The complete set of available metrics can be viewed by clicking **Select Metrics**. Each metric can be expanded by clicking on the "**v**" icon to the right of the metric name. Help is also available for each metric by clicking the "**?**" icon.

72D			Application System He
Select File	Clock Measurements		TDEV
Select Metrics	Port Events	~ ?	TDEV – Time Deviation
View Results	🖉 MTIE	100% V ?	Standards Reference
Generate Report	TDEV	^ ?	I I D-I Necommendation G stU Appendix II (US11046) Estimation Formula
Export	clkFFO	~ ?	TDEV(m ₂) may be estimated by: $\frac{1}{1} \frac{\mu_{-2n+1}}{\mu_{-2n+1}} \left[\frac{\pi_{n+1}}{2} \right]^2$ (11)
	Packet Measurements		$\frac{TDEV(n\tau_0)}{6n^2(N-3n+1)} \sum_{j=1}^{2} \left[\sum_{i=j}^{n} (x_{i+2n}-2x_{i+n}+x_i) \right] n = 1, 2, \dots, \text{integer part}\left(\frac{n}{3}\right)$
	PDV	~ ?	where: Te is the sample period;
	DPD / CDF	~ ?	n is the number of samples n each observation intervat;
	Packet TIE	× ?	T is the measurement period; X ₁ is the i-th time error sample.
	Packet MTIE	~ ?	Noise performance
	Packet TDEV	~ ?	The LDEV(I) converges for all the major hole types anecang actual timing signals. In Table II.3, the characteristic slopes of LDEV(I), for dimetent hole types, are reported. The TDEV(I) allows to discriminate between WPM and FPM noises.
	MATIE	~ ?	Noise process Slope of TDEV(r) WPM v ^{1/2}
	MAFE	~ ?	WFM 1 ^{V2} FFM t
	Packet FFO	~ ?	RWFM T ³²
	FPC	~ ?	Frequency offset and drift Any constant frequency offset of a timing signal, relative to the reference clock, has no influence on TDEV(r).
	FPR	~ ?	For observation intervals τ where a linear frequency drift dominates, the TDEV(τ) behaves as τ^2 .
	FPP	~ ?	Pros and cons For observation intervals where the WPM noise dominates, the behaviour of TDEV(1) significantly depends on sampling period 10.
			TDEV gives more information on the clock noise than MTIE, but it is not suited for buffer characterization.
	Time Error Measurements	7	TDEV is sensitive to systematic effects, which might mask noise components, Adequate filtering must be done on the measured signal before processing TDEV calculation. Diumal wander is an example of systematic effect.
Calculate	Time Error	100% 🗸 ?	TDEV result coming out of network measurement could be heavily influenced by systematic effects.
100%	Time Error (Filtered)	~ ?	
Calnex	Avg Time Error (cTE)	~ ?	

7.3. Performance Test: SyncE Operation

To test the "Ideal Operation" scenario, no impairments are applied to the input of the O-DU.

"Normal Operation" is emulated by applying a wander pattern to the SyncE input of the O-DU. O-RAN.WG4.CUS clause 11.2.5.2 states: Within the O-RAN fronthaul network, all network equipment (NE) supporting SyncE transport across the network shall comply with input and output wander requirements specified in Recommendation ITU-T G.8262 clauses 8.1, 9.1, 9.2 (for EEC) or Recommendation ITU-T G.8262.1 clauses 8.1, 9.1, 9.2 (for EEC)."

If the O-DU supports SyncE, then the applicable limits for SyncE wander tolerance as specified in the ITU-T recommendations above are detailed in the table below.

O-DU	LLS Architecture	SyncE Wander Stimulus
O-DU with EEC	Any	G.8262 Wander Tolerance (same as G.8262.1 Level 2)
O-DU with eEEC	Any	G.8262.1 Level 1 Wander Tolerance

Table 10: SyncE wander limits for O-DU input

7.3.1. Procedure – SyncE Input Test

The test stimulus is automatically selected depending on the selected test within the O-RAN Conformance Test app.

- 1. Navigate to the **O-RAN Conformance Test** app.
- 2. From the O-RAN Conformance Test: drop-down, select the type of test required:
 - O-DU Ideal (no impairment pattern).
 - "O-DU SyncE..." to apply the associated SyncE wander patterns shown in the previous table.



3. In the **Measurement** section, click the **SyncE Wander** and/or **1pps Time Error** checkboxes to enable or disable SyncE or 1PPS measurements depending on the output types generated by the O-DU.

O-RAN Conform	ance Test			
Test:	O-DU SyncE (EEC)	~		
Settling Time:	0 seconds	Apply Undo		
Generation:		Stimulus:	Measurement:	
🗹 РТР	GENERATE	PTP Noise Pattern	🗹 РТР	(START)
🗹 ЕЅМС		PTP Noise Table	1pps Time Error	
	\sim	🗹 SyncE Wander Table	SyncE Wander	DEZ
	СНЕСК	SyncE Wander Offset		
		Estimated Time Remaining	: N/A	⊘ IT
Elapsed Time:	00d 00h 00m 00s	Elapsed Time:	00d 00h 00m 00s	

- 4. In the **ESMC Generation (Port 1)**, confirm that the appropriate settings have been configured to enable the O-DU to use SyncE as a reference as detailed in section 5.4.
- 5. From the Generation section of the Conformance Test app, press Generate. This starts PTP and ESMC message generation, allowing the O-DU to stabilize. Pressing Check will run a simultaneous timing capture and the CAT application will open in a new browser tab. This can be used to check current timing performance prior to starting the test.
 - Wait for the measured output(s) of the O-DU moving from a ramp to stable condition to indicate lock has been achieved.
 - If the O-DU does not achieve lock, then perform troubleshooting of the configuration of the O-DU and Paragon-neo to determine the root cause.
- 6. Once the DUT is stable, in the **Stimulus/Measurement** section, press **Start** to run the measurement.

The **O-DU Ideal** measurement should be run for at least 1000s. The tests that apply stimulus to the SyncE input to the O-DU must be run until at least the *Estimated Time Remaining* has counted down to zero.

O-RAN Conform	ance Test			
Test:	O-DU SyncE (EEC)	~		
Settling Time:	0 seconds	Apply Undo		
Generation:	снеск	Stimulus: PTP Noise Pattern PTP Noise Table SyncE Wander Table SyncE Wander Offset	Measurement: PTP Jpps Time Error SyncE Wander	
Elapsed Time:	00d 00h 00m 07s	Estimated Time Remaining Elapsed Time:	: 00d 04h 11m 12s 00d 00h 00m 05s	

 If testing LLS C2 or C3 architectures, the progress of any applied wander can be observed by navigating to the Status tab of the Wander Generation app. The current position within the table of patterns is indicated by the green box – note that the table can span multiple pages.

✓ Wander Generation Tolerance - Table Sine ✓					_
Status: Wander generation in progress	Settings	Status	Standards		
	Point	Frequency (Hz)	Amplitude (µs)	Dwell (Cycles)	Status
	1	10	0.25	1500	20%
	2	1	0.25	150	0%
	3	0.13	0.25	20	0%
	4	0.016	2	4	0%
	5	0.0032	2	4	0%
Time Remaining 00d 04h 12m 05s				Pag	e 1 of 4 🔣 🕅

7.3.2. Results Analysis

1. From the **O-RAN Conformance Test** app, click on **CAT.** The Calnex Analysis Tool will open in a new browser tab displaying the default metrics.



2. The **Test Environment** function automatically configures the displayed metrics, masks, and thresholds to a range of preset values such as those required for testing compliance to device or network standards.

Select the appropriate **Test Environment** for the current test and O-DU output type. This step and the following steps should be repeated for each output type: PTP and/or 1PPS.



3. Navigate to the available metrics by using the tabs at the top of the window.



4. The O-DU performance meets requirements when the output is within the applied masks and thresholds. This is indicated in the top-right area of the CAT display.



Note: The complete set of available metrics can be viewed by clicking **Select Metrics**. Each metric can be expanded by clicking on the "**v**" icon to the right of the metric name. Help is also available for each metric by clicking the "**?**" icon.

⊂⁄1T			Application System Hel
Select File	Clock Measurements	?	TDEV
Select Metrics	Port Events	~ ?	TDEV – Time Deviation
View Results	S MTIE	100% v ?	Standards Reference
Generate Report	TDEV	^ ?	ITU-T Recommendation G 810 Appendix II (08/1996) Estimation Formula
Export	Tpps TE Absolute		TDEV(nt ₀) may be estimated by:
	CIKFFO	~ ?	$TDEV(n\tau_0) \cong \sqrt{\frac{1}{6n^2(N-3n+1)} \sum_{i=1}^{N-2n+1} \left[\sum_{i=1}^{n+i-1} (x_{i+2n}-2x_{i+n}+x_i)\right]^2}, n = 1, 2,, integer part \binom{N}{2}$
	Packet Measurements		where:
	PDV	~ ?	To is the sample period;
	PDD / CDF	~ ?	r is une number of samples it could use value in the value of the val
	Packet TIE	~ ?	T is the resourcement period, X is the I-th time error sample.
	Packet MTIE	~ ?	Noise performance
	Packet TDEV	~ 7	The TDEV(r) converges for all the major noise types affecting actual timing signals. In Table II 3, the characteristic slopes of TDEV(r), for different noise types, are reported. The TDEV(r) allows to discriminate between WPM and FPM noises.
	MATIE	~ ?	Noise process Slope of TDEV(1) WPM 11172
	MAFE	~ ?	rrw r WFM 1 ¹ 2 FFM t
	Packet FFO	~ ?	RWFM 1 ^{3/2}
	FPC	~ ?	Frequency offset and drift Any constant frequency offset of a timing signal relative to the reference clock, has no influence on TDEV(1)
	FPR	~ 7	For observation intervals 1 where a linear frequency drift dominates, the TDEV(1) behaves as 1 ² .
			Pros and cons
	E HY	v v	For observation intervals where the WPM noise dominates, the behaviour of TDEV(r) significantly depends on sampling period r ₀ .
	Time Error Measurements		TDEC greates interminated of the coordinates which match on a long components; Adequate filtering must be done on the measured signal before processing TDEV is sensitive to systematic effects, which might mask noise components; Adequate filtering must be done on the measured signal before processing TDEV collability. Durant work of its an comment of systematic effect
Calculate	Time Error	100% 🗸 ?	TDEV result coming out of network measurement could be heavily influenced by systematic effects.
100%	Time Error (Filtered)	~ ?	
Calnex	Avg Time Error (cTE)	~ ?	

7.4. Performance Test: Simultaneous PTP and SyncE Noise

The **O-RAN Conformance** app currently does not have an option to automatically apply PTP and SyncE impairments simultaneously, therefore this procedure uses the **PTP** preset. The functionality to automatically apply the test steps below within the O-RAN Conformance app will be available in a future release.

This procedure specifies the "Network Noise" PTP impairment pattern (not "Sines") because it is more representative of real network conditions and additionally the "Sines" patterns are 40 minutes in duration and therefore do not allow enough time for the full suite of SyncE impairment tones to run (approx. 3-4 hours dependent on the pattern). However, the user can select other PTP impairment patterns to run, and repeat them if required, to ensure good test coverage against the SyncE tones.

1. Set up the Paragon-neo and O-DU as detailed in Sections 4 and 5 of this document with one change: in the **Run Apps** page, in the **Presets** panel select the **PTP** preset, not the *O-RAN Conformance* preset:



- 2. In the ESMC Generation (Port 1) app, press Generate to begin ESMC Generation on Port 1.
- 3. In the **PTP Emulation** app, press **Generate** to begin generating PTP. The O-DU should now begin to synchronize to the Paragon-neo.
- 4. In the **PTP Impairments (Port 1)** app, select the **O-DU G.8271.1 Ref Point C (Noise)** pattern, then press **Impair** to begin the PTP impairment.

PTP Impairments ((Port1)			
IMPAIR	Elapsed Time 00d 09h 10m 00s Time Remaining N/A	ØT	Settings Status Pattern: O-DU G.8271.1 Ref Point C (Noise) Repeat: No	
Status: Press IMPAIR to	begin PTP impairment.			

Allow the device to settle after instantaneous change in cTE that is inherent in the impairment pattern. There is no specification for the maximum settling time however 10 minutes is reasonable.

- 5. In the **SyncE Wander Generation** app, configure one of the following **Tolerance Table Sine** wander patterns as appropriate for the O-DU under test as detailed in Table 10 in Section 7.3 of this document:
 - Standard: G.8262 Option 1
 - Standard: G.8262.1

SyncE Wander Generation Status: Press GENERATE to begin v	Tolerance - Table Sine Frequency Offset Tolerance - Single Sine Tolerance - Table Sine Tolerance - G 8262 Option 1 MTIE Tolerance - G 8262 Option 1 TDEV Tolerance - G 8262 Option 2 TDEV	Setting: Standard	s I: <mark>G.8</mark>	Status S	tandards		
	Tolerance - G.8262.1 Level 1 MTIE	Poir	nt	Frequency	Amplitude	Dwell	Page 1 of 4
	Transfer - Table Sine			(Hz)	(µs)	(Cycles)	
	Transfer - G.8262 Option 2 TDEV		1	10	0.25	1500	
			2	1	0.25	150	
-		◀	3	0.13	0.25	20	
	Time Remaining		4	0.016	2	4	Reset
GENERATE	00d 00h 00m 00s		5	0.0032	2	4	Apply

- 6. If measuring the O-DU 1PPS signal, in the 1pps Time Error Measurement + Time of Day app, press Measure.
- 7. In the SyncE Wander Generation app, press Generate to begin the SyncE impairment.
- 8. Note that the *"Table Sines"* are approx. 3-4 hours long, progress can be monitored using the *"Time Remaining"* indicator in the *SyncE Wander Generation* app. As the "Network Noise" PTP impairment profile is approx. 9 hours long the SyncE Wander must be restarted by the user when it completes to ensure continuous SyncE Wander is applied throughout the full PTP impairment pattern this requires two restarts and monitoring of the SyncE impairment progress. If the SyncE is not restarted immediately this is acceptable, however it should be restarted within 10 minutes. The ability to repeat SyncE Wander "Table Sines" will be available in a future release.
- 9. Wait for the PTP and SyncE wander impairment patterns to complete and **Stop** all measurements.

7.4.1. Results Analysis

1. From the **PTP Emulation** app, click on **CAT.** The Calnex Analysis Tool will open in a new browser tab displaying the default metrics.



2. The **Test Environment** function automatically configures the displayed metrics, masks, and thresholds to a range of preset values such as those required for testing compliance to device or network standards.

Select the appropriate **Test Environment** for the current test. This step and the following steps should be repeated for each output type: PTP and/or 1PPS.



3. Navigate to the available metrics by using the tabs at the top of the window.



4. The O-DU performance meets the requirements when the output is within the applied masks and thresholds. This is indicated in the top-right area of the CAT display.



Note: The complete set of available metrics can be viewed by clicking **Select Metrics**. Each metric can be expanded by clicking on the "**v**" icon to the right of the metric name. Help is also available for each metric by clicking the "**?**" icon.

C∕IT			Application System He
Select File	Clock Measurements		TDEV
Select Metrics	Port Events		TDEV - Time Deviation
View Results	S MTIE 100		Standards Reference
Generate Report	TDEV The TE Absolute		ITU-1 Heccommendation G 810 Appendix II (USY1996) Estimation Formula
Export		TDEV(mg) may be estimated by:	
	CikFFO	~ ?	$TDEV(n\tau_0) \cong \sqrt{\frac{1}{6n^2(N-3n+1)} \sum_{i=1}^{N-3n+1} \left[\sum_{i=1}^{n+i-1} (x_{i+2n} - 2x_{i+n} + x_i)\right]^2}$, $n = 1, 2,, integer part \left(\frac{N}{n}\right)$
	Packet Measurements		where:
	DDV		To is the sample period;
	PDD / CDF	∏ PDD / CDF	n is une number to samples in each ouce vanual nine van, γ is the observation interval, equal to π ₀ ; N is the total number of samples;
	Packet TIE		T is the measurement period; Xi is the I-th time error sample.
	Packet MTIE		Noise performance
	Packet TDEV		The TDEV(r) converges for all the major noise types affecting actual timing signals. In Table II.3, the characteristic slopes of TDEV(r), for different noise types, are reported. The TDEV(r) allows to discriminate between WPM and FPM noises.
	MATIE		Noise process Slope of TDEV(1) WPM 1 ^{-1/2}
	MAFE		тта т WFM 1 ¹² FFM т
	Packet FFO		RWFM 1 ^{3/2}
	EPC.	~ ?	Frequency offset and drift
	- FFG		Any constant trequency onset or a timing signal, relative to the reterence clock, has no influence on TUE-V(1). For observation intervals I where a linear frequency drift dominates, the TDE-V(1) behaves as r^2 .
	FPR	~ ?	Pros and cons
	EPP		For observation intervals where the WPM noise dominates, the behaviour of TDEV(1) significantly depends on sampling period t ₀ .
			TDEV gives more information on the clock noise than MTIE, but it is not suited for buffer characterization.
	Time Error Measurements	?	TDEV is sensitive to systematic effects, which might mask noise components; Adequate filtering must be done on the measured signal before processing TDEV calculation. Diurnal wander is an example of systematic effect.
Calculate	Time Error 100		TDEV result coming out of network measurement could be heavily influenced by systematic effects.
100%	Time Error (Filtered)		
Calnex	Avg Time Error (cTE)		

7.5. Further Analysis

7.5.1. Applying O-DU Impairment Patterns from O-RAN.WG4.CONFv09.00

The impairment patterns can be downloaded from the Calnex FAQ at the link below:

https://calnexsolutions.atlassian.net/wiki/spaces/KB/pages/1750859782/O-RAN+O-DU+test+patterns

Instructions on how to import and apply them are:

 $\label{eq:https://calnexsolutions.atlassian.net/wiki/spaces/KB/pages/1688404048/Paragonneo+How+do+I+load+impairment+files+if+they+re+not+already+on+the+instrument the strument the strum$

Follow the steps in Section 7.4 of this document using the imported PTP impairment pattern instead of the built-in pattern, optionally applying SyncE wander if desired.

7.5.2. Further Test Scenarios

Testing the O-DU in real network conditions can also provide more insights into expected device performance. The Calnex Sentinel and Paragon-x products can be used to capture real-life network performance and can be imported into Paragon-neo as impairment profiles.

7.5.3. PTP Decode and Analysis

Launching **PFV** allows decode and display PTP field information in a new browser tab. If the PFV option is installed on the Paragon-neo unit, conformance checking to defined PTP profiles with pass/fail analysis is also possible. For further information please refer to the **PFV Getting Started Guide**.

թե	7									Files	РТР ТоД	Report Sy:	stem Hel	ip
▲! ▼! Rules	set File: G.82	275.1_Phase_Profile.xm	hl	View Rules						Selected p	oacket #:		Go T	ГО
Direction	Packet#	Arrival Time	Decoded PTP Version	Inter Message Time	Message Type		Ethernet Header							88 C)
			I II Version	(410)		SourceAddress	DestinationAddress	EtherType	FCS	transportSpecific	versionPTP	reservedField0	messa	
	42785	769.874999976000	2.0	0.062499992000	DEL-REQ	a0:00:00:00:00:02	1:1b:19:00:00:00	0x88f7	0x82c9abbf	0x0	0x2	0x0	(
		769.875088108000	2.0	0.062500288000	DEL-RESP	0:01:c1:00:ee:b0	1:1b:19:00:00:00	0x88f7	0xa27d1536	0x0	0x2	0x0	(
													(
◄ 2			2.0	0.062499992000	DEL-REQ	a0:00:00:00:00:02	1:1b:19:00:00:00	0x88f7	0x9efe5ac4	0x0	0x2	0x0	(U	
► 2			2.0	0.062499616000	DEL-RESP	0:01:c1:00:ee:b0	1:1b:19:00:00:00	0x88f7	0xcd8574ac	0x0	0x2	0x0	(
													(
		769.943051564000		0.069892384000	ANNOUNCE		1:1b:19:00:00:00	0x88f7	0x3c7ba1c9	0x0	0x2	0x0	()	
			2.0	0.062500032000	DEL-REQ	a0:00:00:00:00:02	1:1b:19:00:00:00	0x88f7	0xcb782b75	0x0	0x2	0x0	()	
			2.0	0.062500287750	DEL-RESP	0:01:c1:00:ee:b0	1:1b:19:00:00:00	0x88f7	0x2457908f	0x0	0x2	0x0	(
								0x88f7	0x6ceaca5f	0x0		0x0	(
◄ 2			2.0	0.062499992000	DEL-REQ	a0:00:00:00:00:02	1:1b:19:00:00:00	0x88f7	0xe102dbab	0x0	0x2	0x0	(
			2.0	0.062499616000	DEL-RESP	0:01:c1:00:ee:b0	1:1b:19:00:00:00	0x88f7	0x67b8e628	0x0	0x2	0x0	(
			2.0										(
								0x88f7	0x437af6cd	0x0		0x0	(
	42799	770.124999984000	2.0	0.062499992000	DEL-REQ	a0:00:00:00:00:02	1:1b:19:00:00:00	0x88f7	0x9c24ac8d	0x0	0x2	0x0	()	
	42800		2.0	0.062500256000	DEL-RESP	0:01:c1:00:ee:b0	1:1b:19:00:00:00	0x88f7	0x271732f1	0x0	0x2	0x0	(
₩ ► 2		770.129405387500											(
◄ 2	42802		2.0	0.062499992000	DEL-REQ	a0:00:00:00:00:02	1:1b:19:00:00:00	0x88f7	0x8b34fa7c	0x0	0x2	0x0	()	
			2.0	0.062500287750	DEL-RESP	0:01:c1:00:ee:b0	1:1b:19:00:00:00	0x88f7	0xe1fbe52c	0x0	0x2	0x0	(
► 2								0x88f7	0x6de83d5a					
	_													
						Message:	Rate (msg/sec) 😑	Inter-mess	age Interval	Count		EAU		2
												THE	E7 E00/	
						SYNC	15.82 FOL	LOW-UP				iotai Pass Rate:	07.00%	
Calnex			DEL-REQ	16.00 DEL	-RESP	16.00		Tol	tal Counts					
						PDEL-REG	PDE	L-RESP	PDE	EL-RESP-FUP	Pa	ickets	44969	
						ANNOUNC	E 7.76 SIG	NALING	MAI	NAGEMENT	En	rored Packets	19075	

8. O-DU CONF 3.3.8 Performance Test

This test is defined in Document O-RAN.WG4.CONF.0-R003-v09.00, O-RAN Working Group 4 (Fronthaul Working Group) Conformance Test Specification clause 3.3.8.

This performance test is mandatory if the O-DU contains an embedded local PRTC using a GNSS receiver. This test is defined assuming a Full Timing Support (FTS) profile on all PTP ports.

8.1. Test Description

This section provides information about the test requirements and the applicable timing signal types.

8.1.1. O-DU Performance Requirements

The overall synchronization performance of an O-DU is defined in the O-RAN Working Group 4 (Open Fronthaul Interfaces WG) Control, User and Synchronisation Plane Specification document O-RAN.WG4.CUS.0-R003-v13.00, Section 11, with additional information in Annex H. The CUS specification defines key synchronization parameters that must be met:

Table 11:	CUS Key	Synchronization	Parameters
-----------	---------	-----------------	------------

Metric	Limit	Reference
Network Time Error Budget (MaxITEL)	1.420μs (LLS-C1) 1.325μs (LLS-C2) 1.5 μs (LLS-C3 & LLS-C4)	Table 11.3.2.1-1
Maximum Absolute Frequency Error (MaxIFEI)	15ppb (Class A O-DU) 5ppb (Class B O-DU)	Table 11.3.2.1-1

O-RAN.WG4.CONF 3.3.8 defines tests that validate the conformance to the CUS specifications above by measuring performance of the O-DU outputs.

Two scenarios are tested, Ideal Operation and Normal Operation:

- 1. Ideal Operation: The time source provides "ideal" O-DU synchronization input with no implicitly added dynamic or constant time error.
- 2. Normal Operation: This is currently in O-RAN CONF as "for further study". However Calnex document CX3016 Paragon-neo PRTC Test Guide provides guidance on testing these scenarios and, additionally, degraded scenarios.

The performance specification of an O-DU for both scenarios is:

- a. Maximum 0.1 Hz low pass filtered frequency error for LLS-C1 and LLS-C2 deployment configurations:
 - ±15 ppb for class A O-DU
 - ± 5 ppb for class B O-DU
- b. Maximum 0.1 Hz low pass filtered time error:
 - ±1420 ns for LLS-C1
 - ±1325 ns for LLS-C2.
 - ±1500 ns for LLS-C3 and LLS-C4

The thermal conditions are not defined by O-RAN. The tests are intended to be run at a constant temperature, but the specific temperature conditions to be used are to be decided by the device vendor.

8.1.2. Timing Signal Types

O-RAN.WG4.CONF clause 3.3.7 states: "For LLS-C1 and LLS-C2 configuration, the test is set up to measure frequency and time error at one of the Ethernet master fronthaul ports of the O-DU. For LLS-C3 and LLS-C4 configuration, the test is configured to measure time error on a measurement port of the O-DU, typically a 1PPS signal if available or an unused Ethernet port."

Regarding PLFS (typically SyncE) output from the O-DU, O-RAN.WG4.CUS clause 11.2.3, for LLS C1 deployments states: "*in the specific case where O-RU does not make use of PLFS, in which case PLFS emission shall be optional for the O-DU*". Therefore, SyncE measurement is optional in this specific case.

The above means that depending on the specific deployment configuration, functionality of the O-DU, and the SyncE requirement of the O-RU, performance **measurements must be made on the PTP, and optionally the SyncE and/or 1PPS outputs from the O-DU.**

8.2. Performance Test: O-DU with Embedded GNSS Receiver

In this configuration the O-DU implements a PRTC, the document *CX3016 Paragon-neo PRTC Test Guide* provides full guidance regarding how to test a device, in this case the O-DU, for the performance requirements of a PRTC as defined in G.8272 and G.8272.1. To test for the performance requirements defined in O-RAN.WG4.CONF, follow the procedure below using the captures from the tests performed.

8.2.1. Results Analysis

1. From the Paragon Neo Application interface, launch the CAT application by clicking on any CAT button:



2. The Calnex Analysis Tool will open in a new browser tab. Navigate to the **Select File** screen and select **Close All** to unload any currently loaded captures.

⊄ IT	Application	System Help
Select File	Open File Open Trace Import Settings	Close All
Select Metrics		Close
View Results		Close

- 3. The Calnex Analysis Tool will open in a new browser tab. Navigate to the **Select File** screen and select **Close All** to unload any loaded captures.
- 4. Click on **Open File** and select the files required for analysis from the dialog box that appears. Holding down the *Control* button on the keyboard allows multiple files to be selected. Click **Open** to open the file(s).



5. When the files have loaded, click View Results, the measurements will be displayed with the default metrics applied.



- 6. The **Test Environment** function automatically configures the displayed metrics, masks, and thresholds to a range of preset values such as those required for testing compliance to device or network standards.
- 7. Select the appropriate **Test Environment** for the current test and O-DU type.



8. Navigate to the available metrics for the Test Environment by using the tabs at the top of the window.



9. The O-DU performance meets requirements when the output is within the applied masks and thresholds. This is indicated in the top-right area of the CAT display.



Note: The complete set of available metrics can be viewed by clicking **Select Metrics**. Each metric can be expanded by clicking on the "**v**" icon to the right of the metric name. Help is also available for each metric by clicking the "**?**" icon.

T EQ			Application System Hel
Select File	Clock Measurements		TDEV
Select Metrics	Port Events		TDEV – Time Deviation
View Results	🖉 MTIE		Standards Reference
Generate Report	TDEV		ITU-1 recommendation G attuAppendix II (Ustate) Estimation Formula
Export	Tµps re Ausonne		TDEV(m_{0}) may be estimated by:
	ck/FFO	~ ?	$TDEV(n\tau_0) \cong \sqrt{\frac{1}{6n^2(N-3n+1)}} \sum_{j=1}^{N-2n+1} \left[\sum_{i=j}^{n+j-1} (x_{i+2n} - 2x_{i+n} + x_i) \right]^2, \ n = 1, 2, \dots, \text{integer part}\left(\frac{N}{3}\right)$
	Packet Measurements		where:
	PDV		To is the sample period;
	POD / CDF		n is the number of samples in each observation interval, γ is the observation interval, equal to π ₀ ,
	Packet TIE	~ ?	N is the total number of samples, T is the measurement period,
			A is the Fith time error sample.
	Packet MTIE	~ ?	Noise performance The TDEV(r) converges for all the major noise types affecting actual timing signals. In Table II.3, the characteristic slopes of TDEV(r), for different noise
	Packet TDEV		types, are reported. The TDEV(1) allows to discriminate between WPM and FPM noises.
	MATIE		Noise process Slope of TDEV(t) WPM t ⁻¹²
	MAFE		WFM 1 ^{1/2} FFM T
	Packet FFO		RWFM 1 ^{3/2}
	■ FPC	~ ?	Frequency offset and drift
			For observation intervals t where a linear frequency drift dominates, the TDEV(t) behaves as r^2 .
	FPR	~ ?	Pros and cons
	FPP		For observation intervals where the WPM noise dominates, the behaviour of TDEV(1) significantly depends on sampling period 16-
	Taxa Error Nansuramanta		TDEV gives more information on the clock noise than MTIE, but it is not suited for buffer characterization.
		· ·	TDEV is sensitive to systematic effects, which might mask holds components, Adequate intering must be done on the measured signal before processing TDEV calculation. Diurnal wander is an example of systematic effect.
Calculate	Time Error		TDEV result coming out of network measurement could be heavily influenced by systematic effects.
100%	Time Error (Filtered)		
Calnex	Ava Time Error (cTE)		



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