TEST GUIDE

CX3019 v3.0

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-RAN-compliant environment. This is a critical consideration in the open, mixed-vendor 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.

Contents

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: https://www.calnexsol.com/en/timing-and-sync-blog-article-display/1518-how-is-the-network-changing-and-what-does-this-mean-for-sync

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

O-CU Central Unit

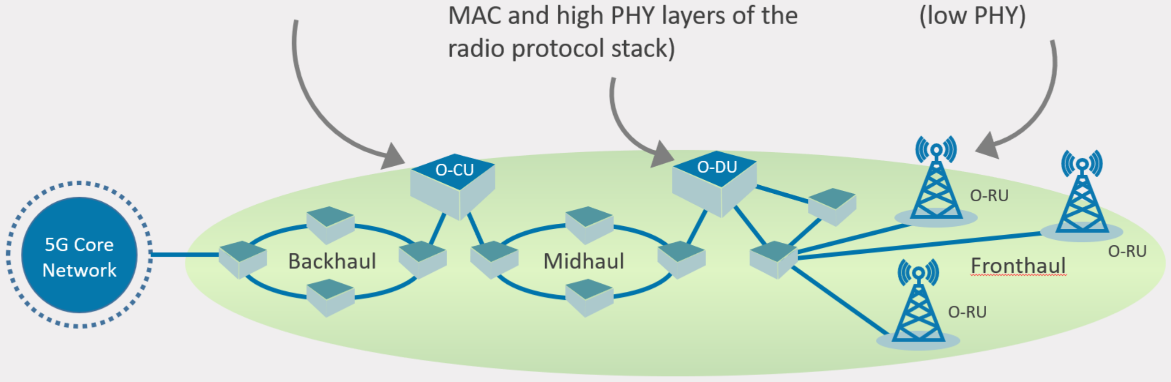
- Centralized location
- Processing the higher layers in the radio protocol stack (e.g. PDCP)

O-DU Distributed Unit

- Collects/distributes traffic from/to O-RUs. Sited where convenient to reach O-RUs
- Baseband processing unit (RLC, MAC and high PHY layers of the radio protocol stack)

O-RU Radio Unit

- Cell towers. Geographically distributed
- Processing the lower layers in the radio protocol stack (low PHY)



3.2. O-RAN Fronthaul Interoperable Elements

M-plane

Management Plane: refers to non-real-time management operations between the O-DU and the O-RU

C-plane

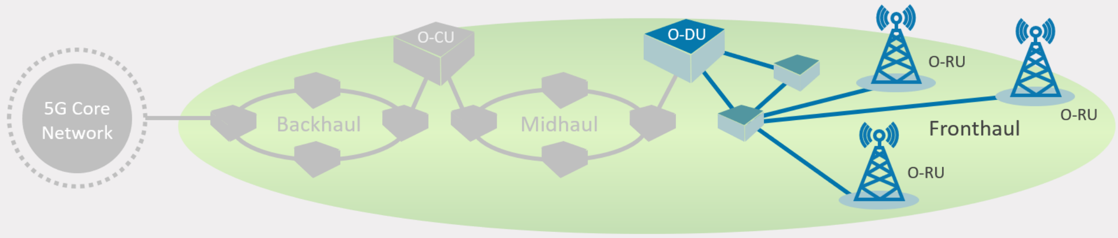
Control Plane: refers specifically to real-time control between O-DU and O-RU

U-plane

User Plane: refers to IQ sample data transferred between O-DU and O-RU

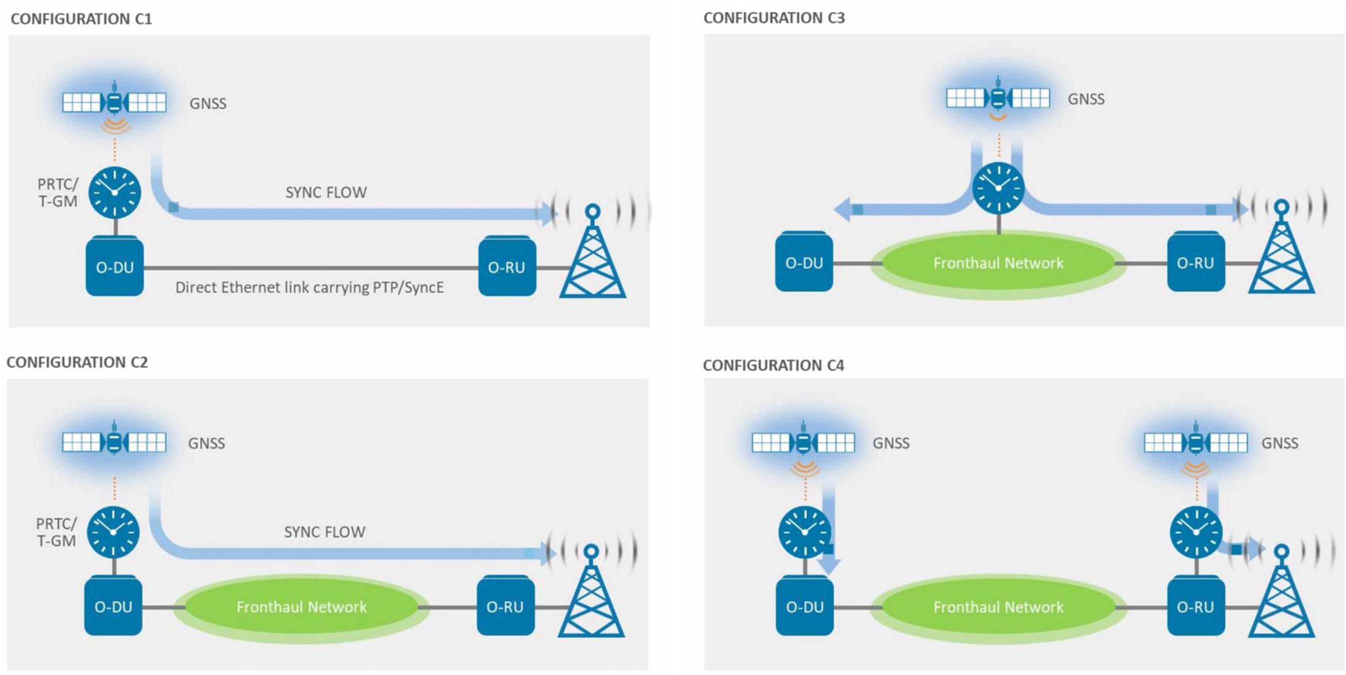
S-plane

Synchronisation Plane: refers to synchronisation between the O-RU or O-DU and a synchronisation controller



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.0-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:

Table 2: Calnex Test Guides

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*

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

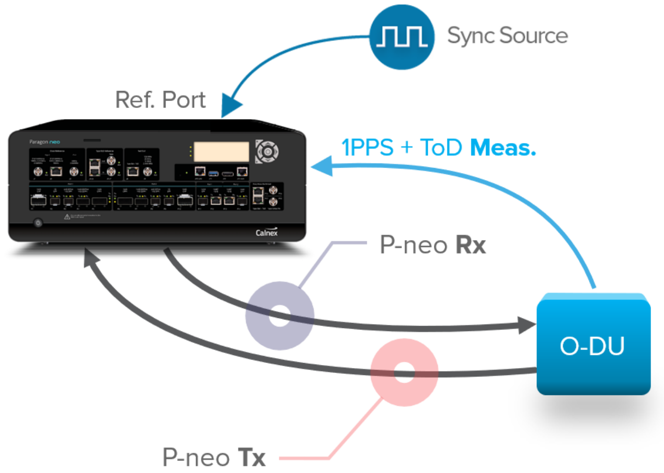
Detailed information regarding the Paragon-neo front panel connections and interfaces are detailed in the *Calnex Paragon-neo Getting Started Guide* that is provided as part of the Paragon-neo on-instrument document set. It is accessible from the **Help** menu in the top right of the Paragon-neo's Graphical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

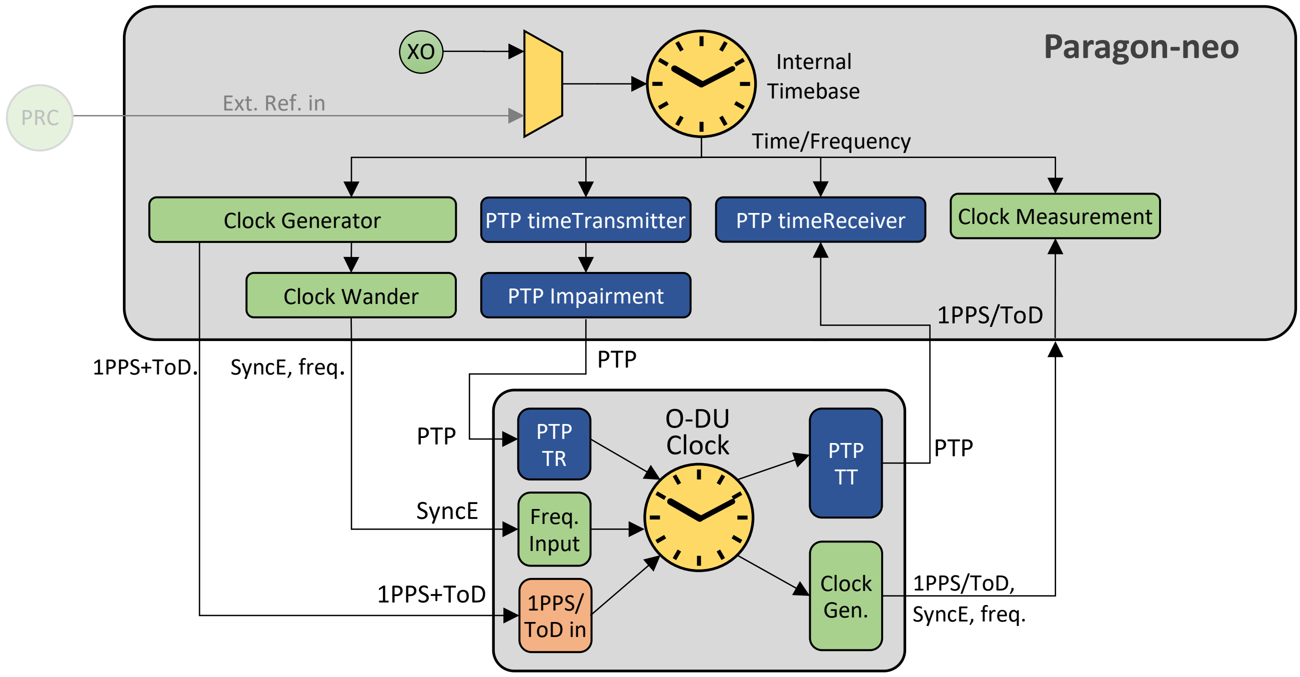


Figure 1: O-DU detailed topology using Paragon-neo

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.

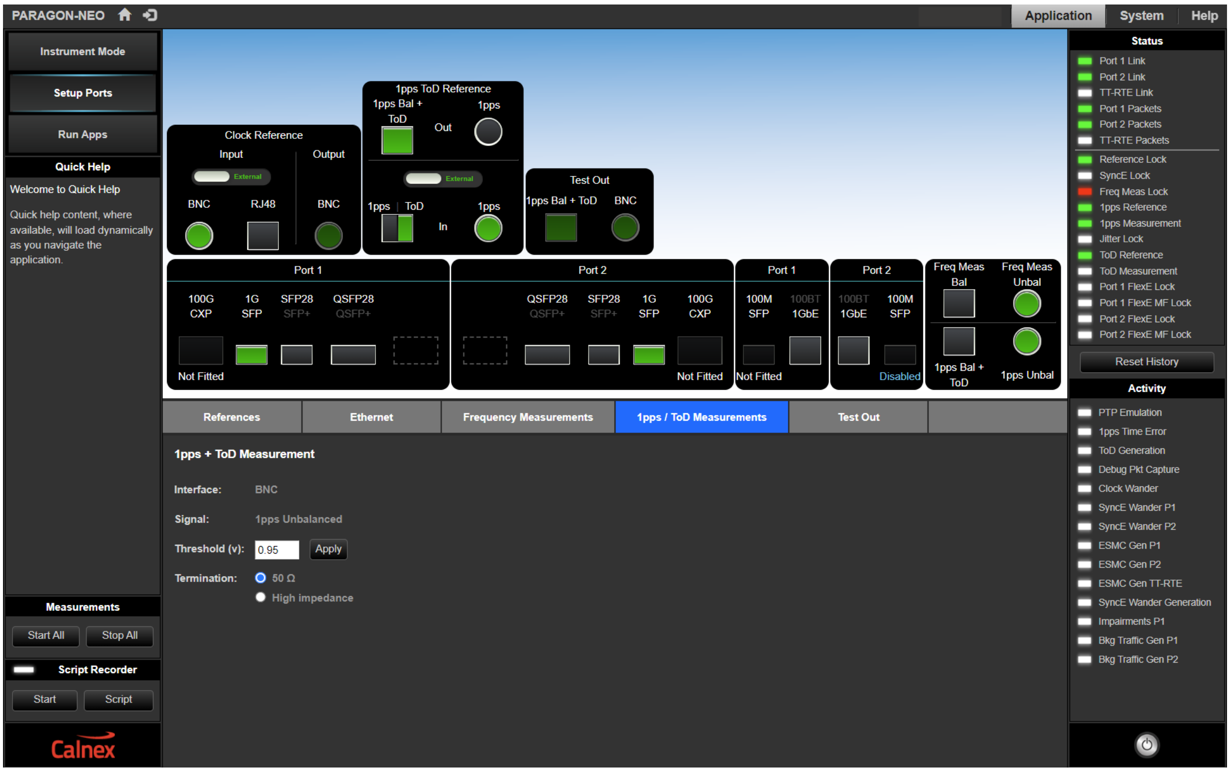
If more details are required, please see the Paragon-neo *Getting Started Guide*.

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.

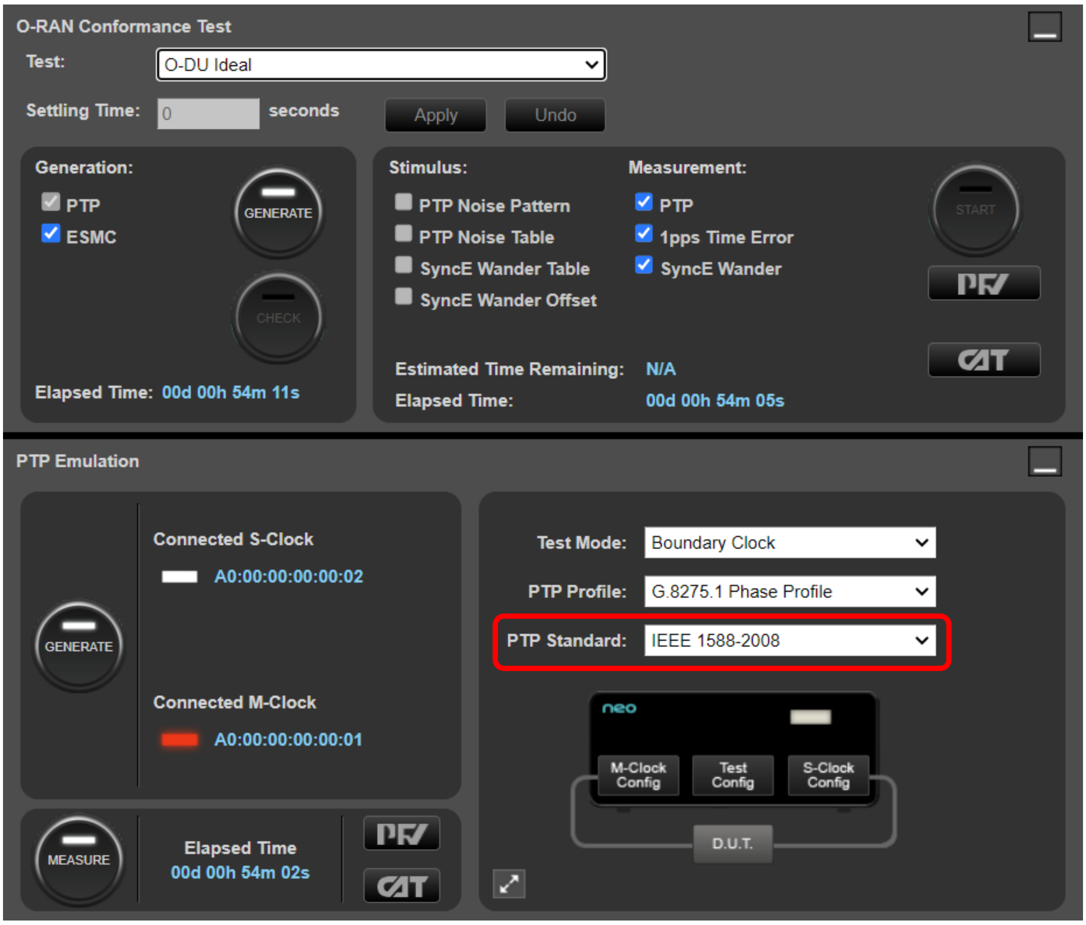
5.4. Device Connection Settings

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.

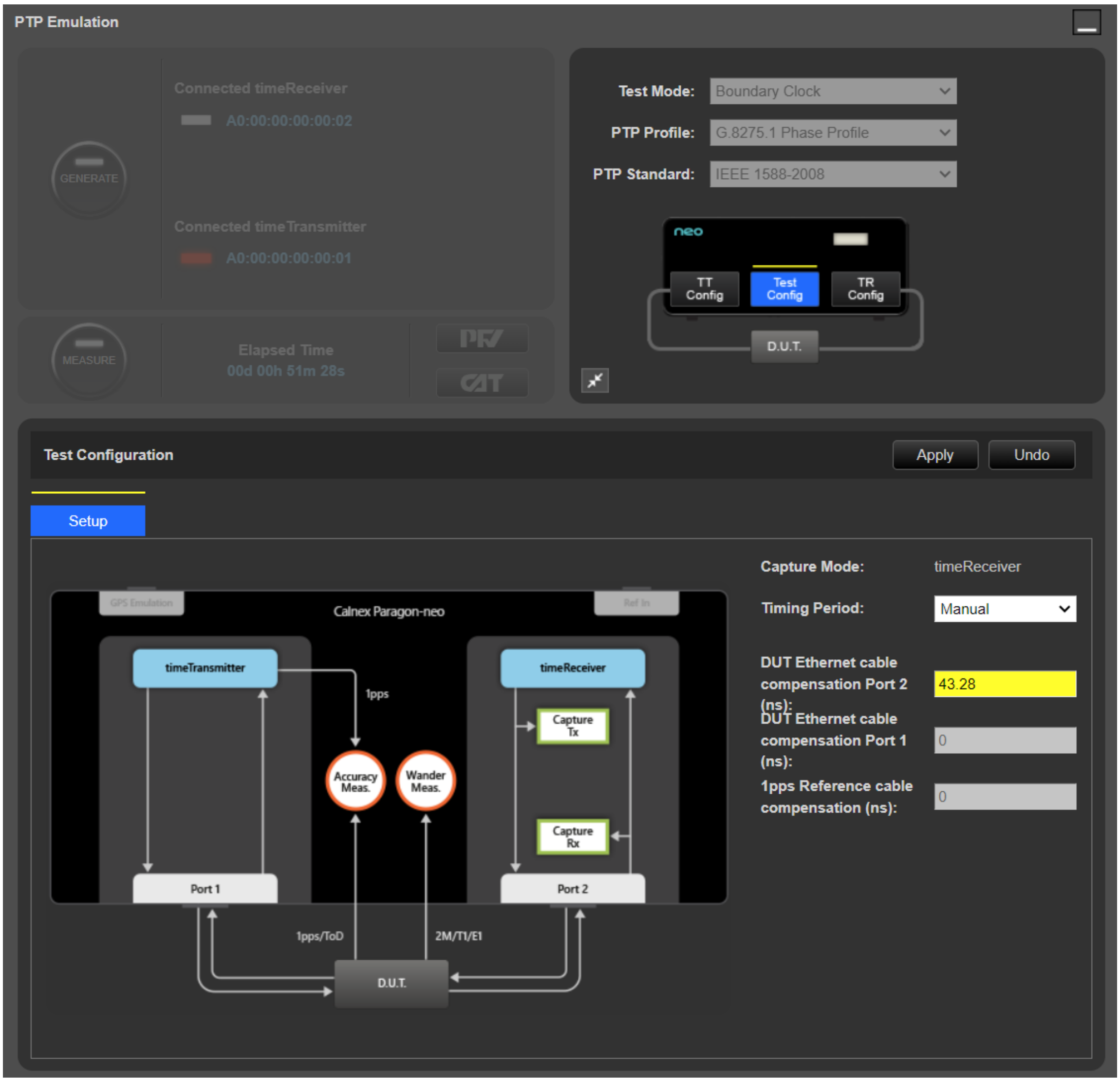
Physical Layer Frequency Support (PLFS), typically SyncE, is mandatory when using G.8275.1 however WG4.CUS clause 11.2.3 states: "*… an O-DU or O-RU end application is not required to use a PLFS to achieve clock (frequency) synchronization…*" The configuration of Paragon-neo should therefore match the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

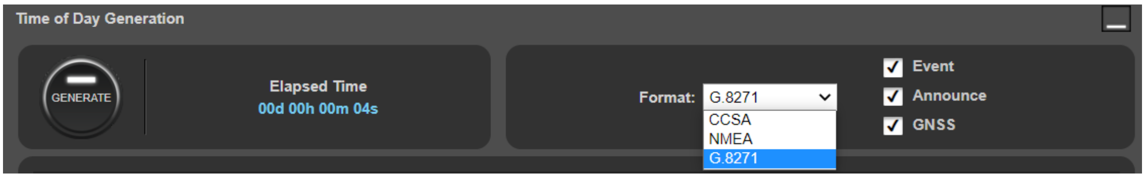
2. In the **PTP Emulation** app, select the appropriate **PTP Standard** for the O-DU.



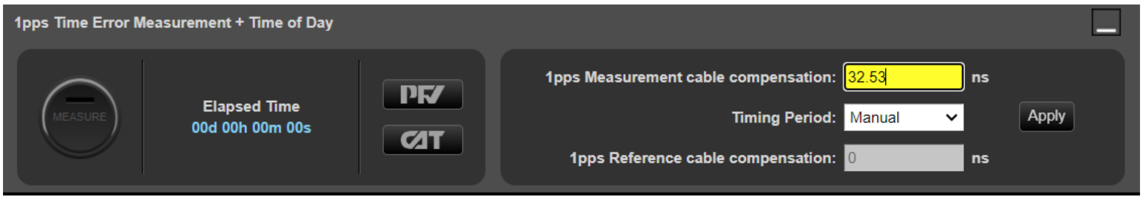
3. Select **Test Config** and enter cable delay values appropriate for the test setup. Delay values are represented in nanoseconds and should be entered to two decimal places (i.e. *x.yy*) for best results. A value of 4.9ns per meter of single-mode optical fiber and 4.94ns/m of multi-mode fiber is typical, 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**.



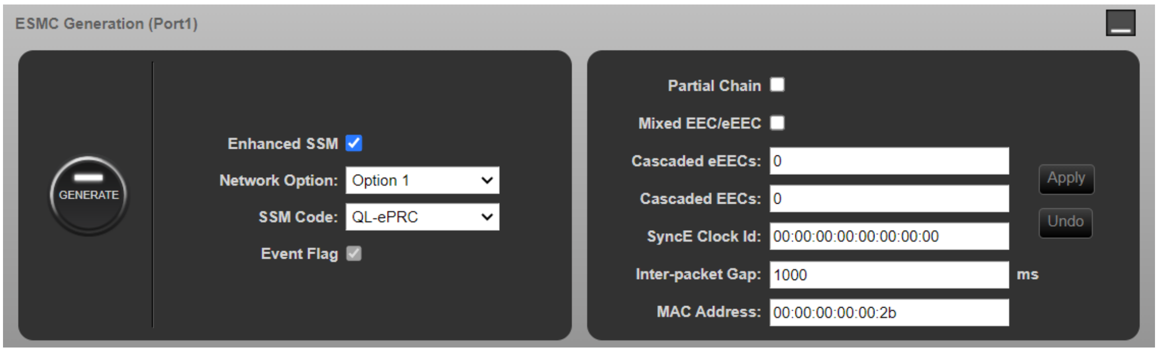
4. If the O-DU requires a 1PPS+ToD input, select the appropriate **Time of Day** message format.



5. 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:



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.



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.

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

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
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:

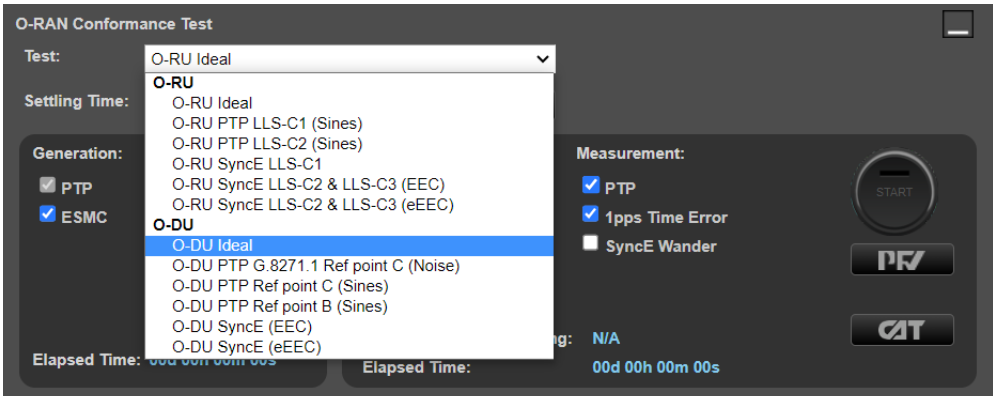
1. **Startup** – initially, Paragon-neo and the O-DU are connected as per Section 4 with no generation active.
2. **Nominal** – Paragon-neo PTP emulation is started, along with ESMC generation if required, with the PTP Clock Class (and SyncE QL value, if applicable) configured such that the O-DU will 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

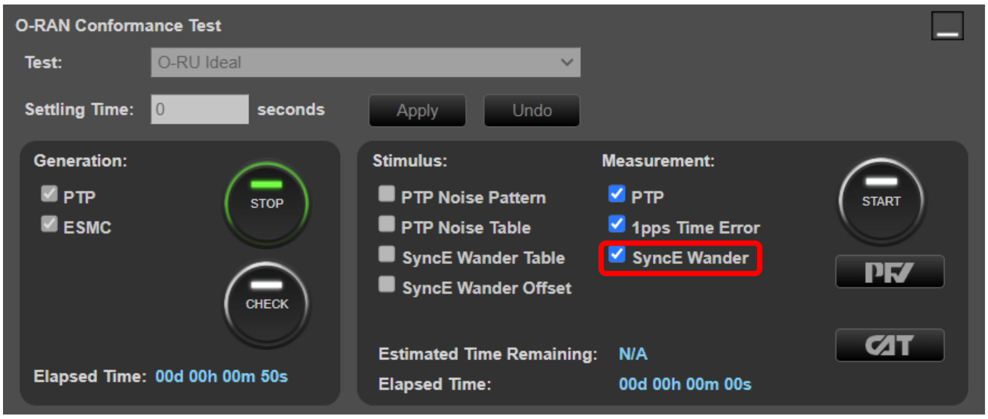
1. Confirm the Paragon-neo is configured as per Section 5, including the PTP and SyncE QL configurations.
2. Confirm that there is no active generation. Power the O-DU off then back on again, this is the *Startup* phase.

   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.**



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.



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.

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

Step	O-DU PTP Status	PTP Input Parameters			PTP/SyncE Output Parameters			
		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) then FREERUN	NOT_ USABLE	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

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.

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

Step	O-DU PTP and SyncE Status	PTP/SyncE Input Parameters					PTP/SyncE Output Parameters			
		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
3	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.	Implementation 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

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*.

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

Step	GNSS RF or PRTC output Status
1	Startup Status (and GNSS Acquiring Mode if implemented) - Note 1
2	Nominal
3	Degraded
4	Nominal
5	Failed (no signal)
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.	

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.

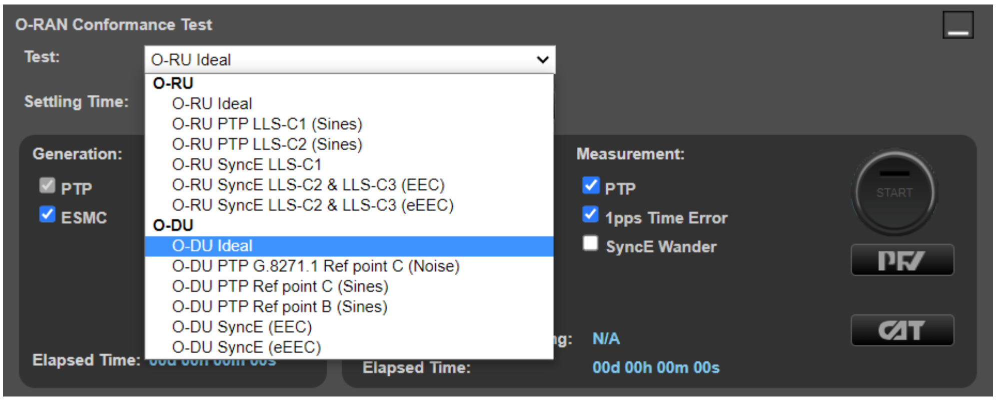
6.2.1. Test Procedure

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.

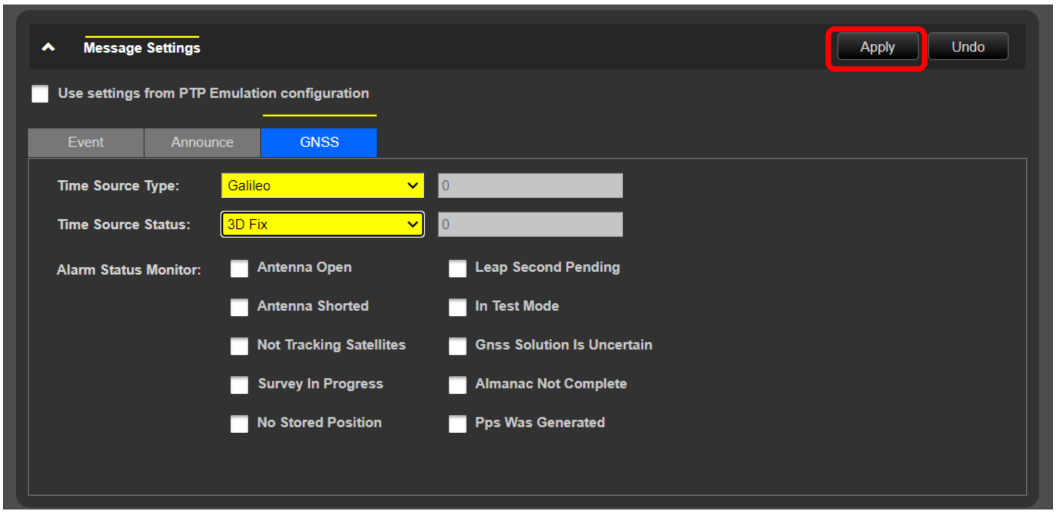
3. Navigate to the **O-RAN Conformance Test** app. From the **Test:** drop-down select **O-DU Ideal.**



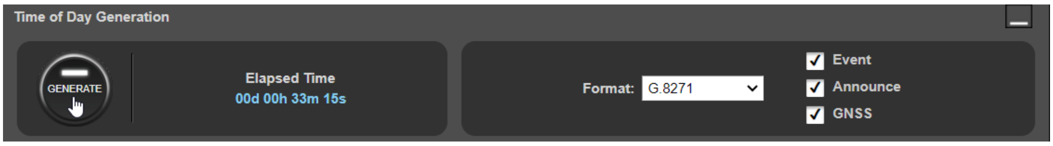
4. Navigate to the **Time of Day Generation** app. From the **Format:** select the message type that the O-DU is configured to receive.

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.



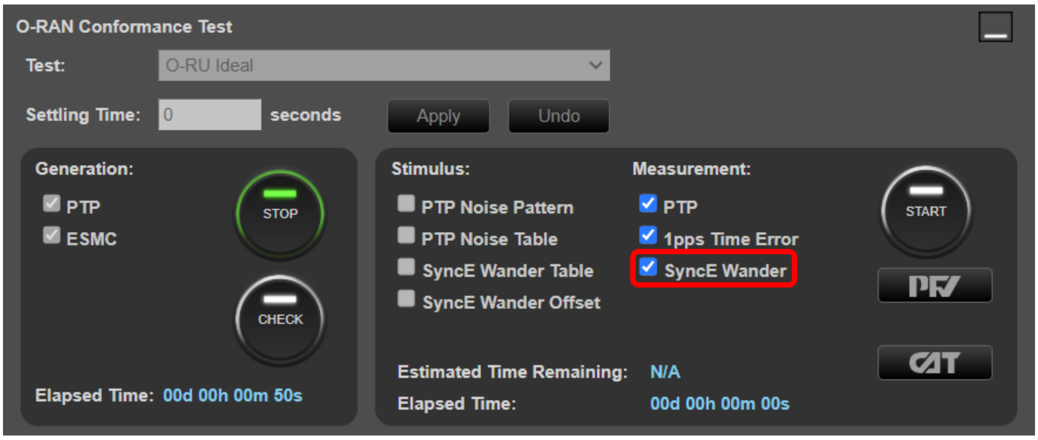
6. From the **Time of Day Generation** app, press **Generate**.



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.



9. 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.

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

Step	O-DU GNSS, Status	GNSS Input Parameters			PTP/SyncE Output Parameters			
		sync -state	gnss sync-source-status	gnss sync-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 2) then NOT_ USABLE	(Notes 1, 3)	NOT_ IN_USE (Note 2) then NOT_ USABLE	Note 1

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.

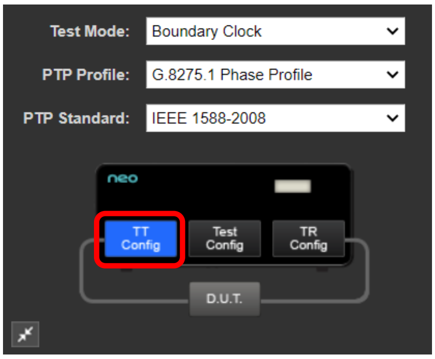
* ‘Received value’ indicates that the output value from the O-DU is the same as that it receives, except for in the *Startup* phase where the output value shall be the O-DU default value as there is no input.

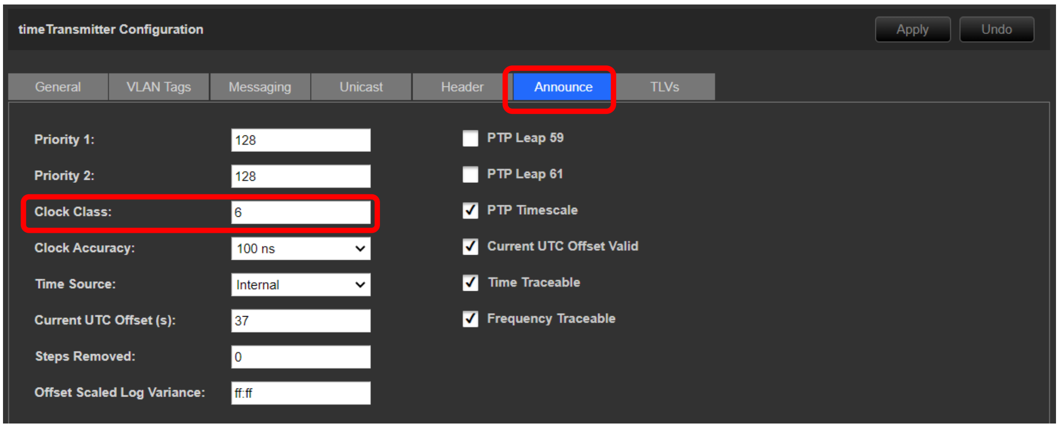
6.3. Changing the Input Conditions

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

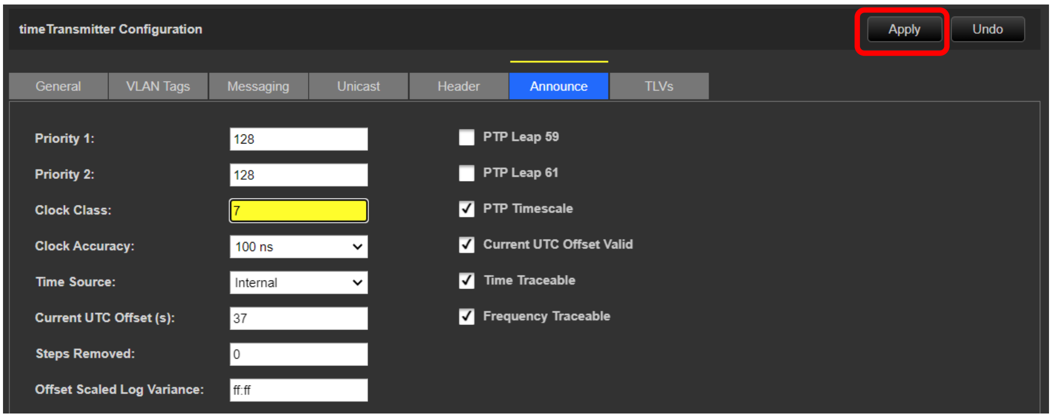
6.3.1. Changing the PTP Clock Class

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:





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.

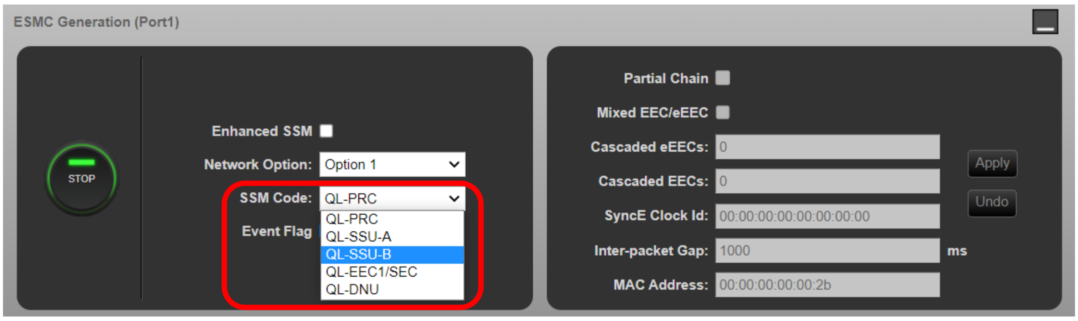


Once applied, the new value will be carried in the Announce message and its effect on the O-DU observed.

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.

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.

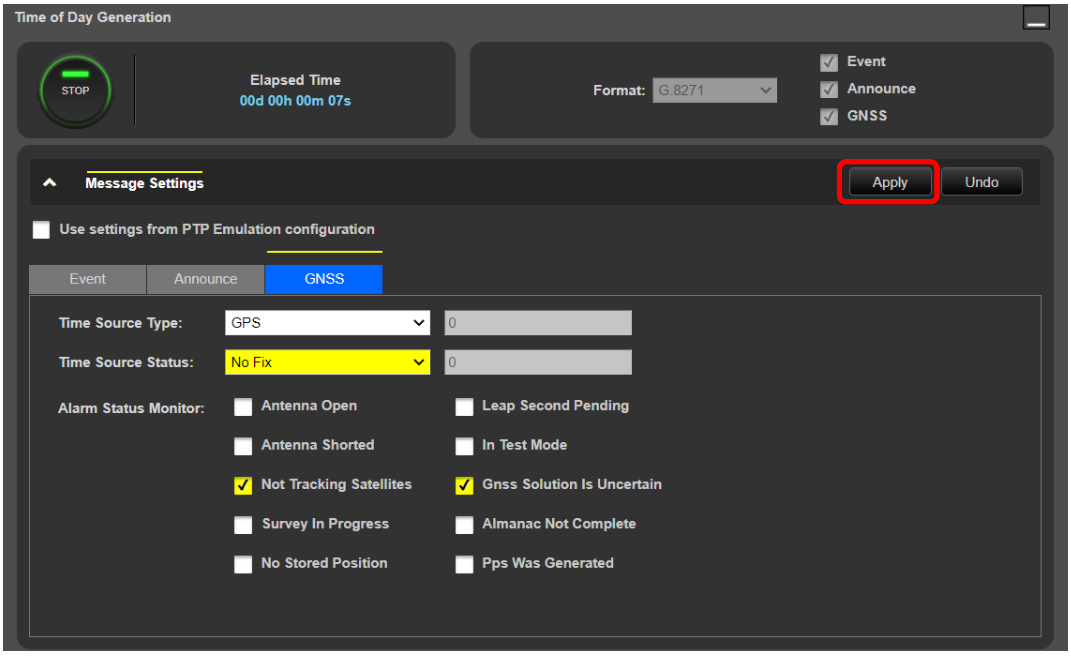
6.3.3. Changing the 1PPS+ToD status

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.

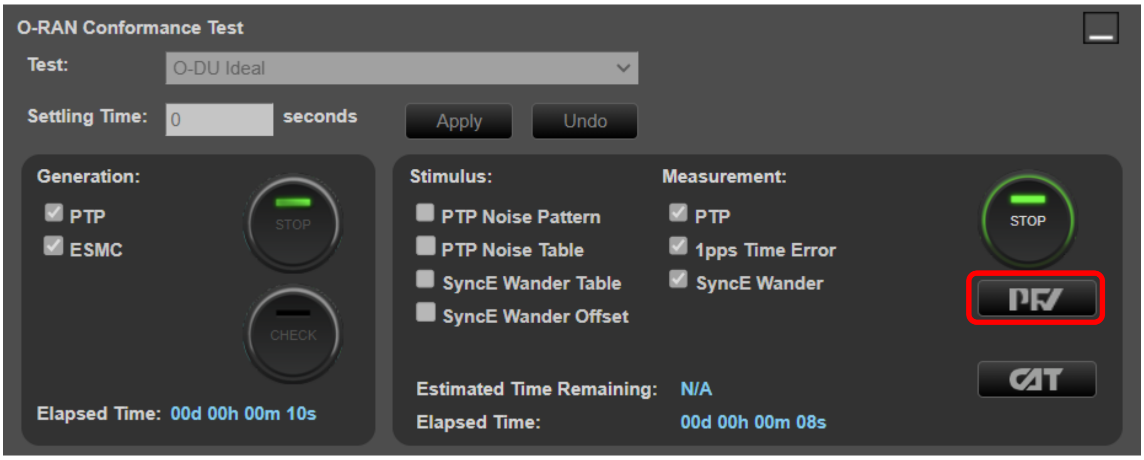


6.4. Using CAT and PFV to Monitor the O-DU Output

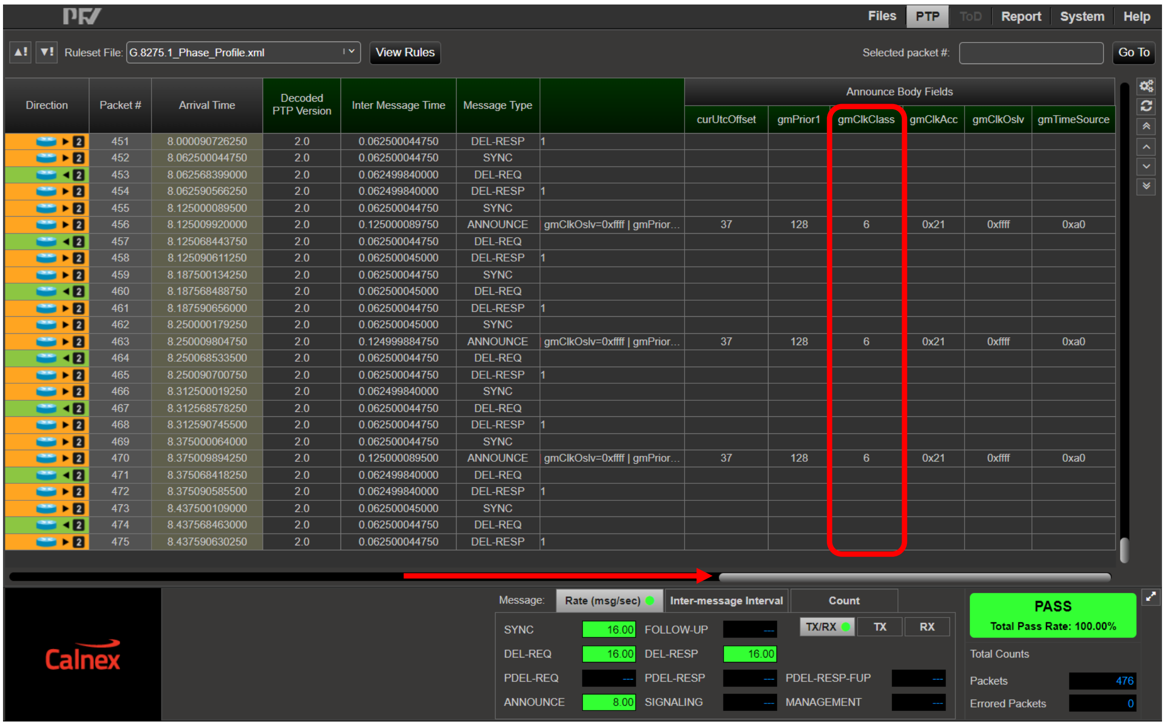
The procedure below shows how to use the CAT and PFV applications to monitor the PTP Clock Class and SyncE QL values being output by the O-DU.

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:



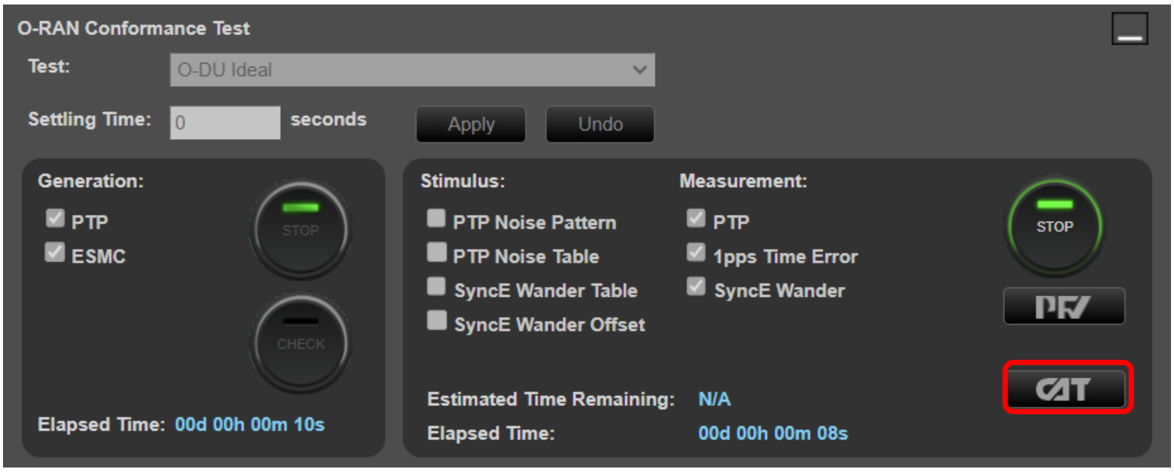
2. In the **PFV** application, use the horizontal scroll bar to navigate to the ***gmClkClass*** column.



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:



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:

ESMC Event #	Elapsed Time (s)	Date / Time	ESMC Quality	
			Tx	Rx
0	0.927	2023-04-20 20:47:19	No ESMC Data Yet	QL-PRC (0x2)
1	148.963	2023-04-20 20:49:47	No ESMC Data Yet	QL-EEC1/SEC (0xb) (E)
2	149.975	2023-04-20 20:49:48	No ESMC Data Yet	QL-EEC1/SEC (0xb)
3	156.965	2023-04-20 20:49:55	No ESMC Data Yet	QL-DNU/DUS (0xf) (E)
4	157.966	2023-04-20 20:49:56	No ESMC Data Yet	QL-DNU/DUS (0xf)
5	163.436	2023-04-20 20:50:02	No ESMC Data Yet	QL-DNU/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 (Max|TE_L|)	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 (Max|FE|)	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.

Table 9: Time error limits for O-DU input

Frequency [Hz]	At Reference Point C		At Reference Point B		Test duration [s]
	dTE Amplitude [ns]	Constant Time Error [ns]	dTE Amplitude [ns]	Constant Time Error [ns]	
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)

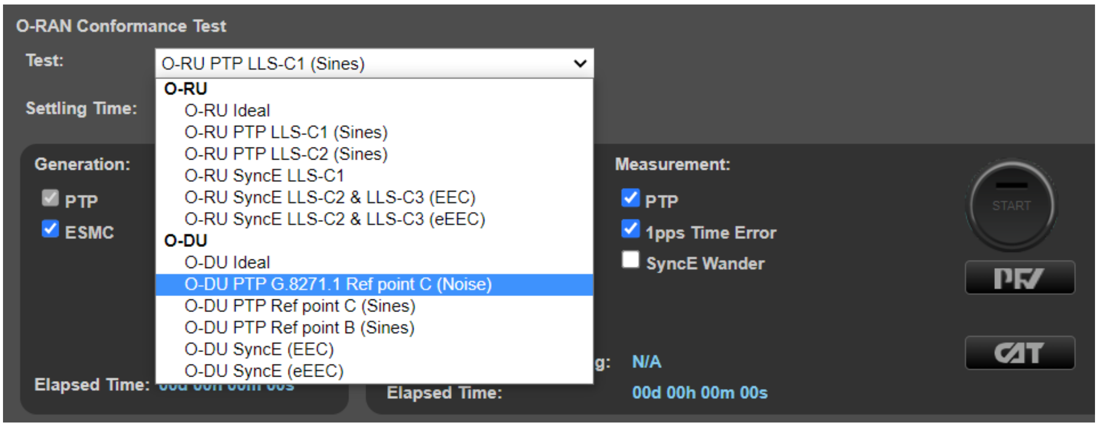
A second method is also defined in O-RAN.WG4.CONF: *"An alternative and more representative method for reference point C is to apply a noise pattern that meets the network limit mask defined in ITU-T G.8271.1, Table 7-1/Figure 7-2. … The advantage of this is that it is more representative of real network 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:

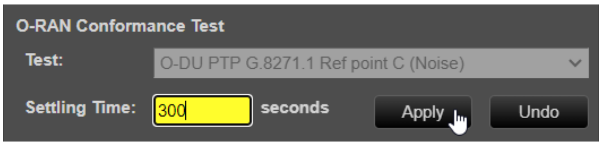
- **O-DU Ideal** (no impairment pattern).
- **O-DU PTP G.8271.1 Ref point C (Noise)** to apply the representative network noise pattern specified in O-RAN.WG4.CONF.
- **O-DU PTP Ref point C (sines)** or **O-DU PTP Ref point B (sines)** to apply the sine wave patterns specified in O-RAN.WG4.CONF.



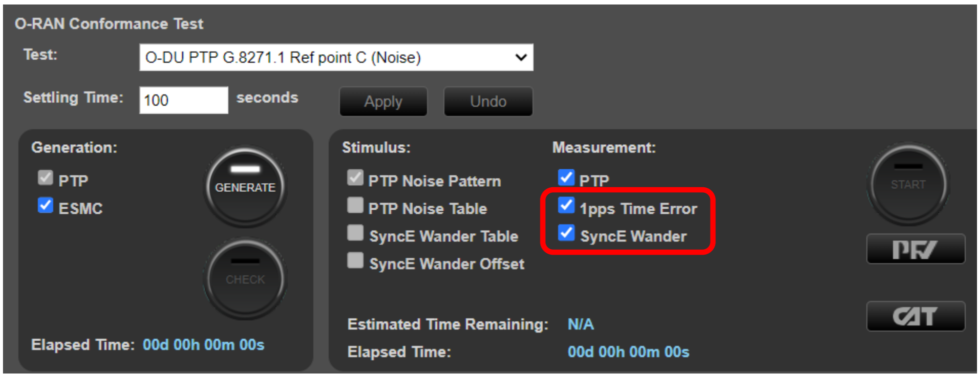
2. The **Settling Time** parameter specifies the amount of time between applying PTP stimulus and starting measurement, allowing the device to settle after instantaneous changes in cTE that are inherent in some of the impairment patterns and are applied when the conformance test is started. There is 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**.



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.



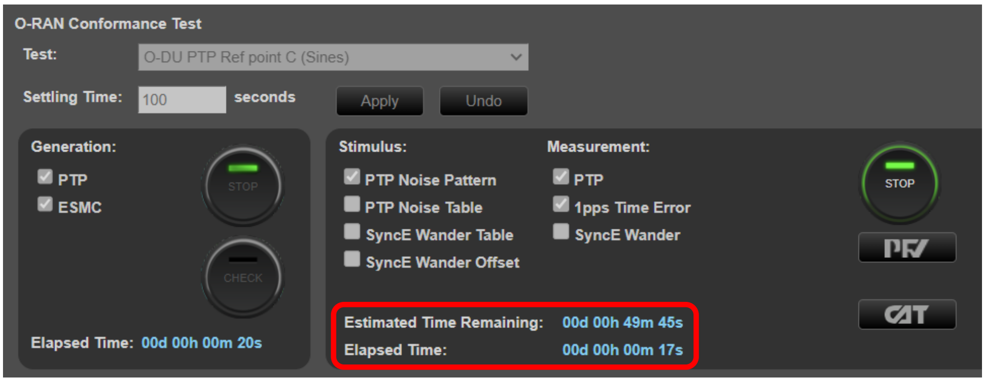
4. If the O-DU uses SyncE, in the **ESMC Generation (Port 1)** app confirm that the appropriate settings have been configured to enable the O-DU to use SyncE as a reference as detailed in section 5.4.

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.

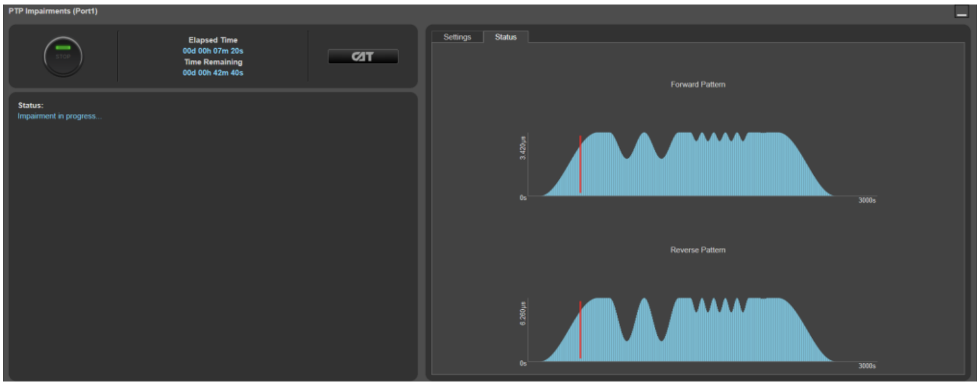
   - Wait for the measured output(s) of the O-DU moving from a ramp to stable condition to indicate lock has been achieved.
   - If the O-DU does not achieve lock, then perform troubleshooting of the configuration of the O-DU and Paragon-neo to determine the root cause.

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.



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.



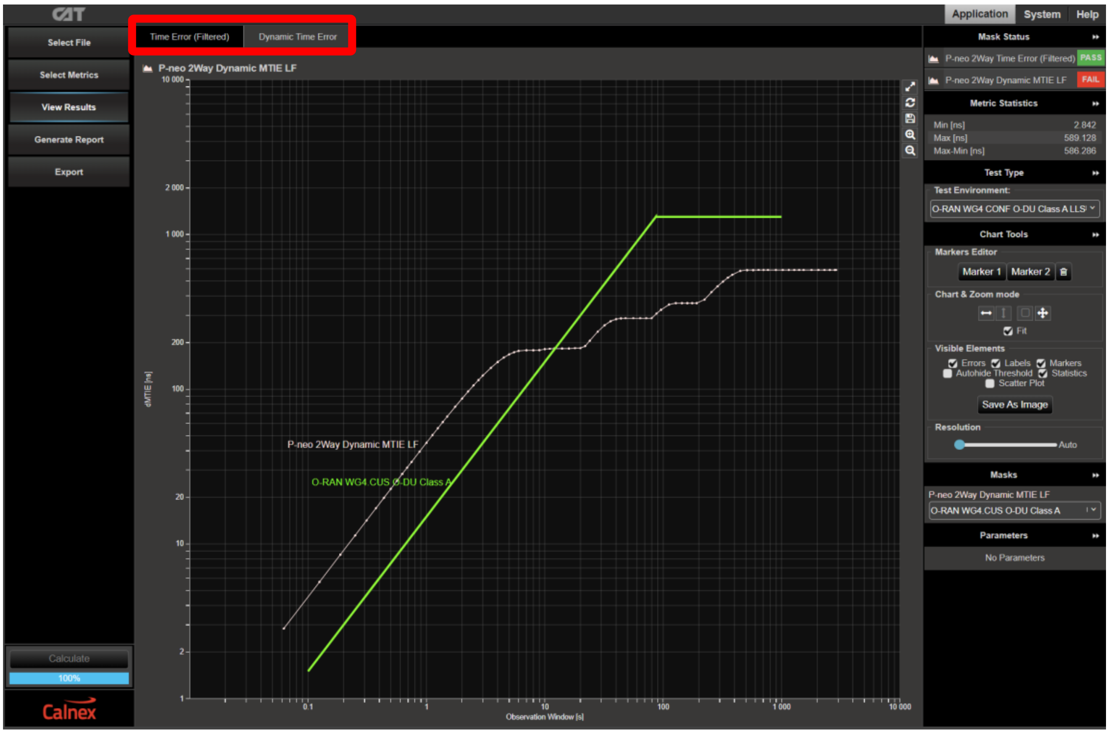
7.2.2. Results Analysis

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.

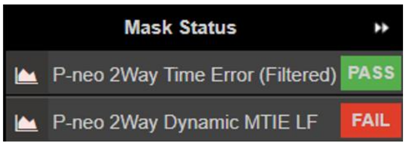
2. The **Test Environment** function automatically configures the displayed metrics, masks, and thresholds to a range of preset values such as those required for testing compliance to device or network standards.

   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.

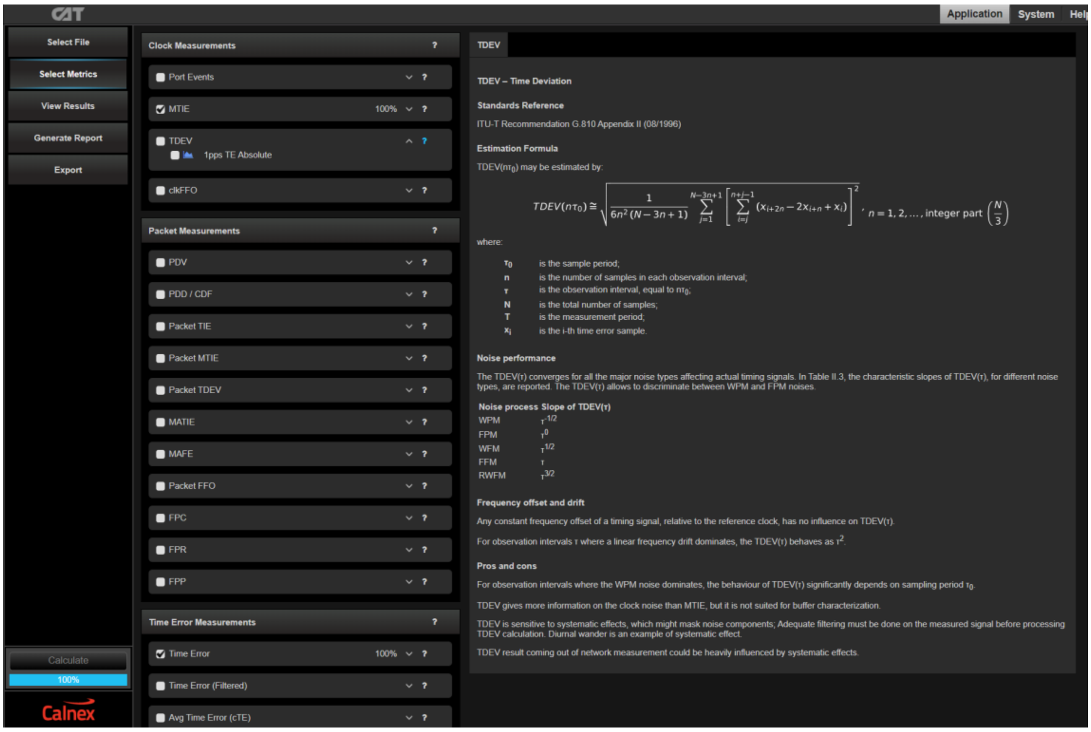
3. Navigate to the available metrics for the Test Environment by using the tabs at the top of the window.



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.



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 eEEC)."*

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.

Table 10: SyncE wander limits for O-DU input

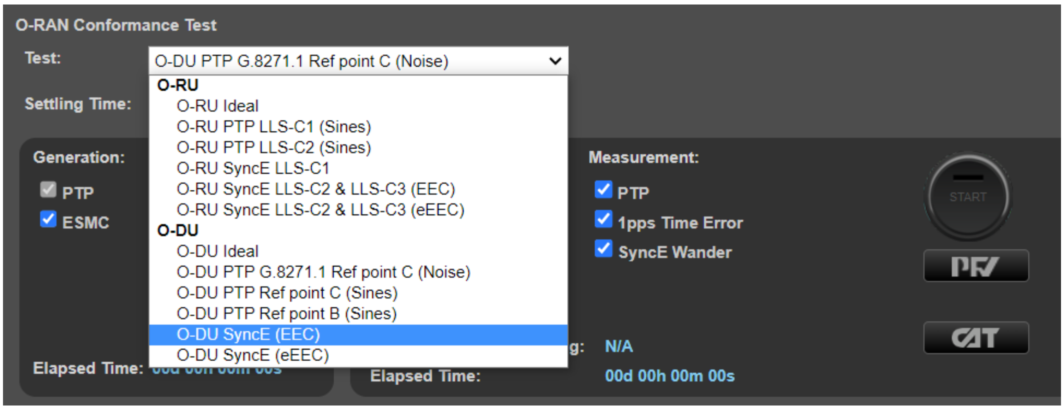
O-DU	LLS Architecture	SyncE Wander Stimulus
O-DU with EEC	Any	G.8262 Wander Tolerance (same as G.8262.1 Level 2)
O-DU with eEEC	Any	G.8262.1 Level 1 Wander Tolerance

7.3.1. Procedure – SyncE Input Test

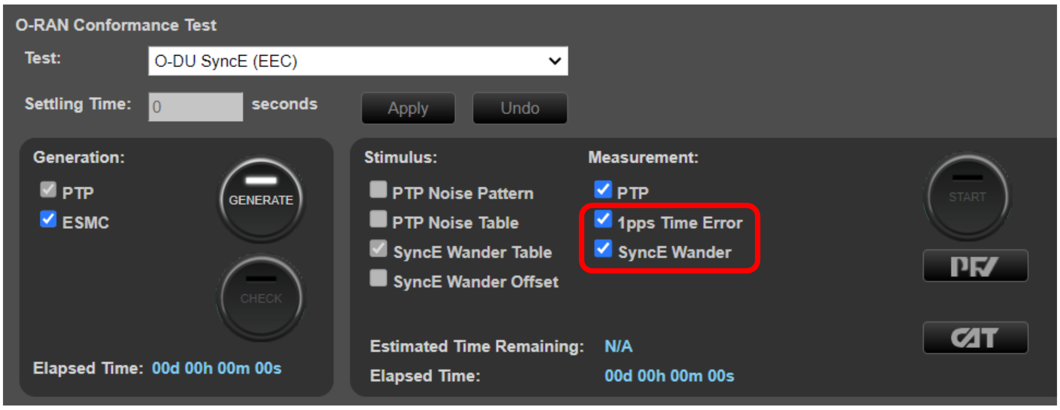
The test stimulus is automatically selected depending on the selected test within the O-RAN Conformance Test app.

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.



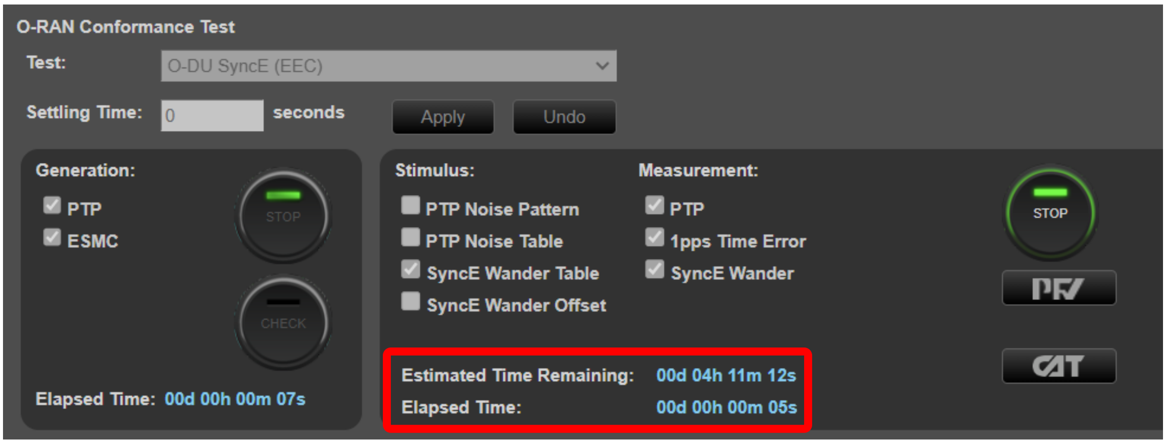
4. In the **ESMC Generation (Port 1),** confirm that the appropriate settings have been configured to enable the O-DU to use SyncE as a reference as detailed in section 5.4.

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.

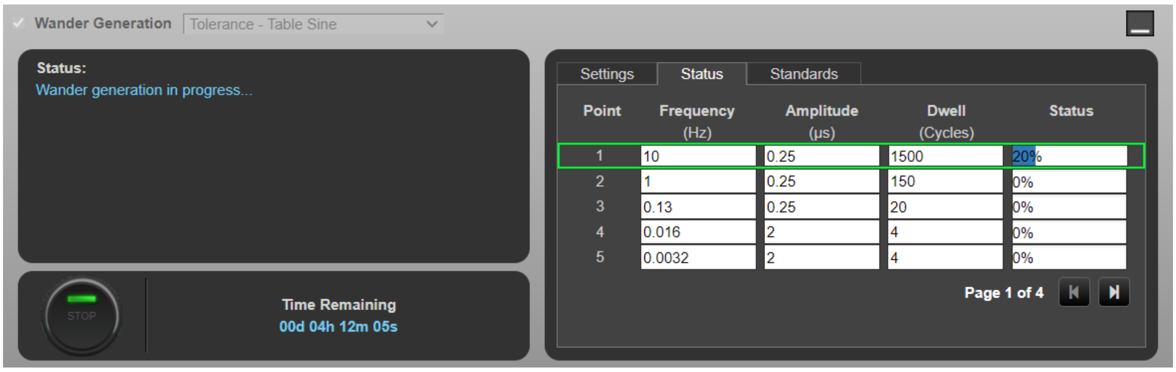
    - Wait for the measured output(s) of the O-DU moving from a ramp to stable condition to indicate lock has been achieved.
    - If the O-DU does not achieve lock, then perform troubleshooting of the configuration of the O-DU and Paragon-neo to determine the root cause.

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.



7. 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.

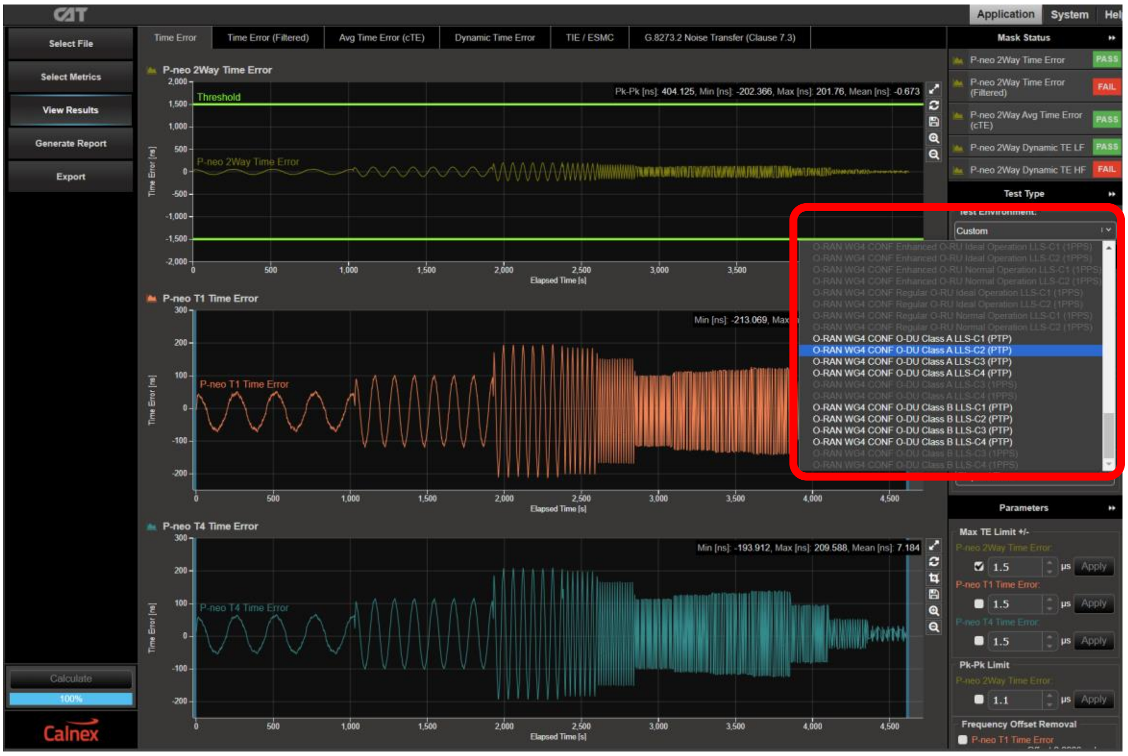


7.3.2. Results Analysis

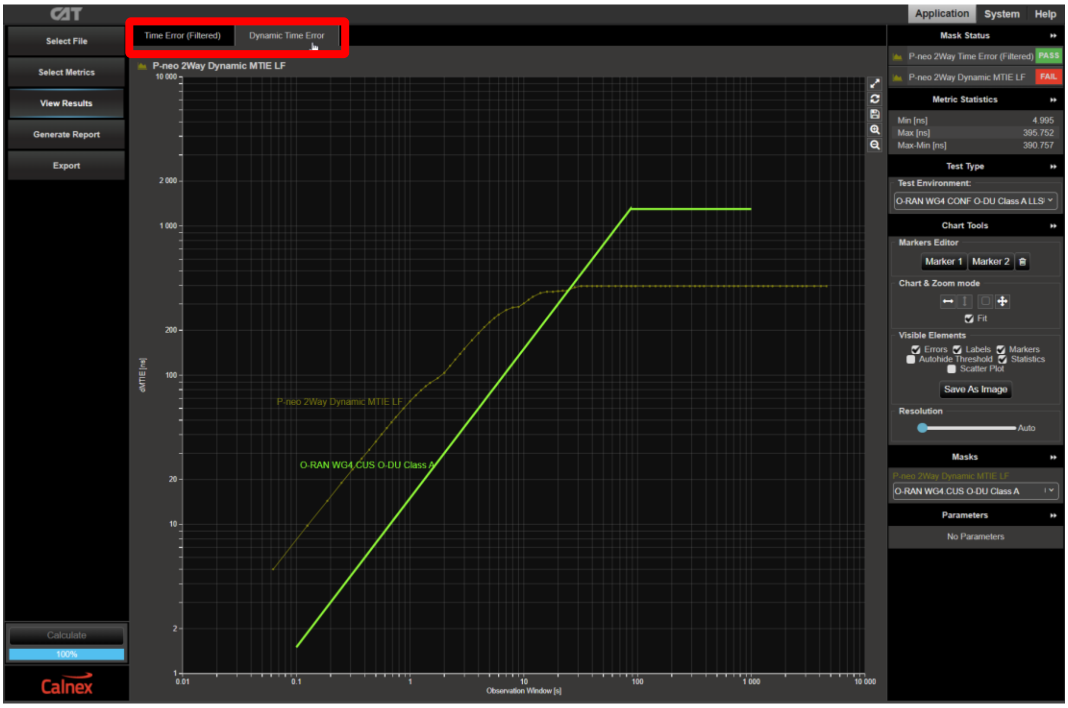
1. From the **O-RAN Conformance Test** app, click on **CAT.** The Calnex Analysis Tool will open in a new browser tab displaying the default metrics.

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.

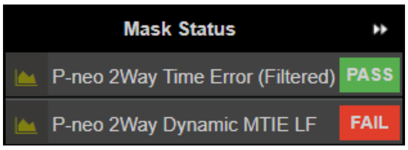
   Select the appropriate **Test Environment** for the current test and O-DU output type. This step and the following steps should be repeated for each output type: PTP and/or 1PPS.



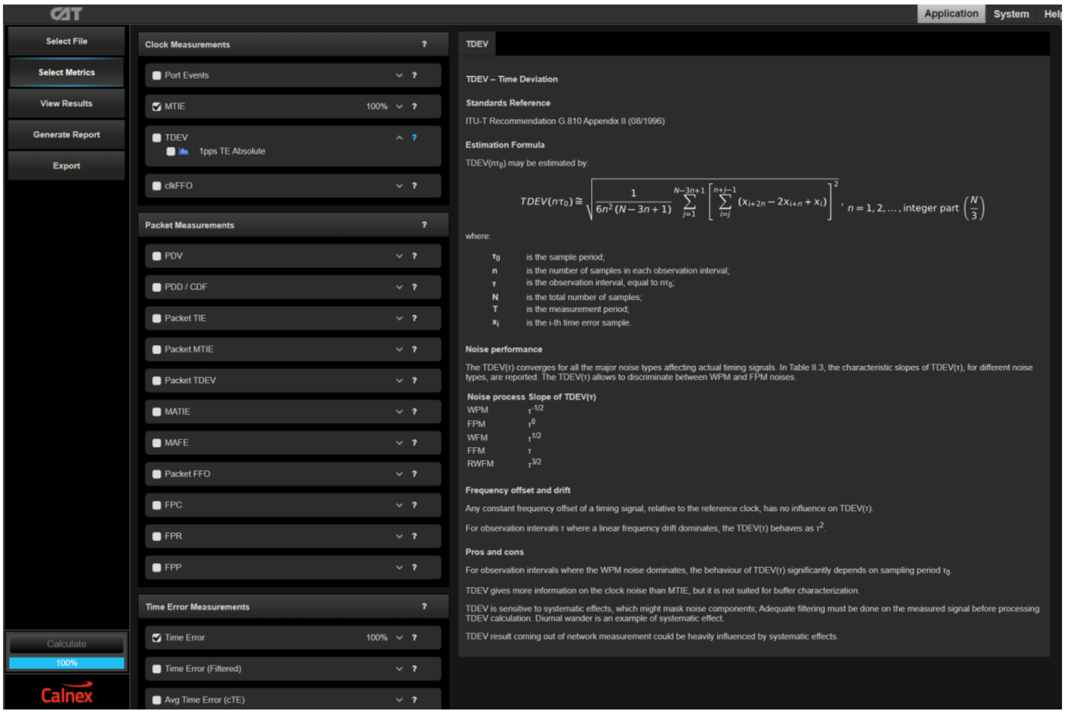
3. Navigate to the available metrics by using the tabs at the top of the window.



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.



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.

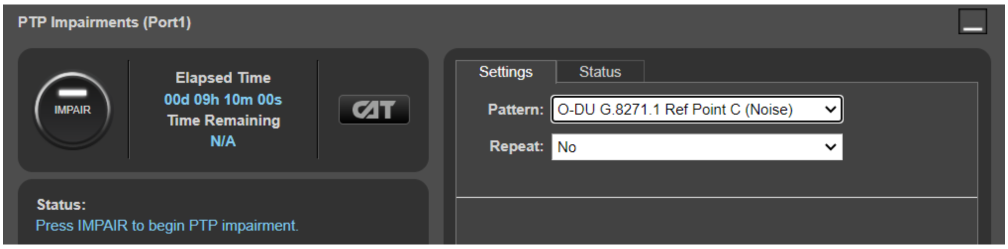
This procedure specifies the "Network Noise" PTP impairment pattern (not "Sines") because it is more representative of real network conditions and additionally the "Sines" patterns are 40 minutes in duration and therefore do not allow enough time for the full suite of SyncE impairment tones to run (approx. 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.

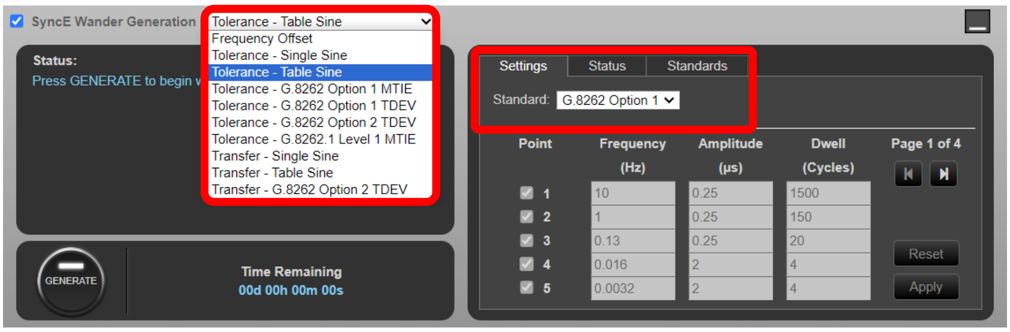
4. In the **PTP Impairments (Port 1)** app, select the **O-DU G.8271.1 Ref Point C (Noise)** pattern, then press **Impair** to begin the PTP impairment.



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***



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.

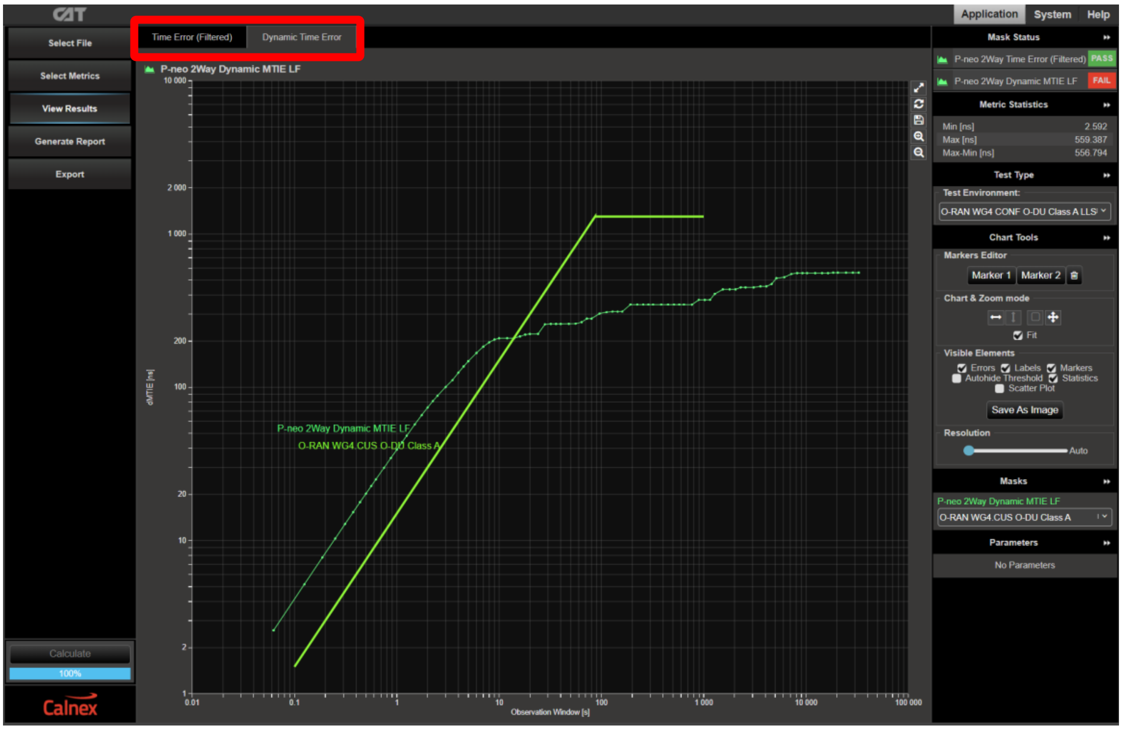
7.4.1. Results Analysis

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

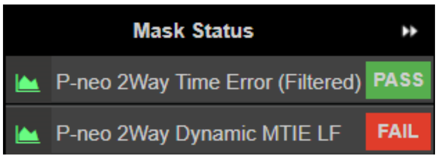
2. The **Test Environment** function automatically configures the displayed metrics, masks, and thresholds to a range of preset values such as those required for testing compliance to device or network standards.

   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.

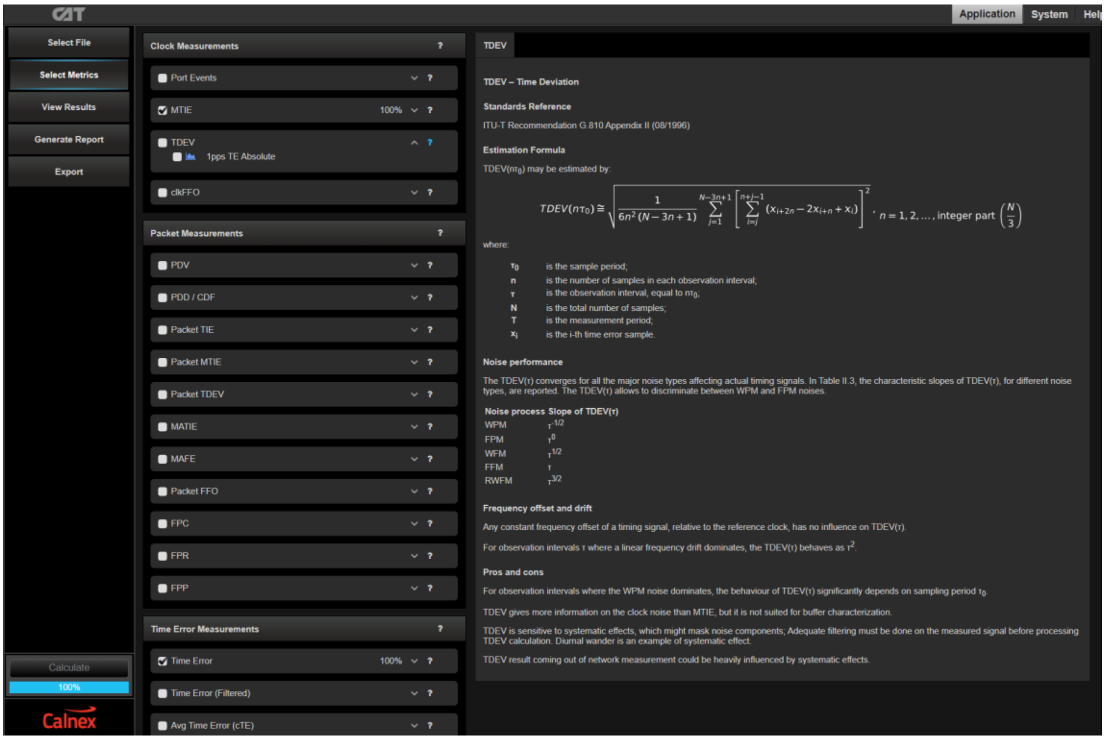
3. Navigate to the available metrics by using the tabs at the top of the window.



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.



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:

https://calnexsolutions.atlassian.net/wiki/spaces/KB/pages/1688404048/Paragon-neo+How+do+I+load+impairment+files+if+they+re+not+already+on+the+instrument

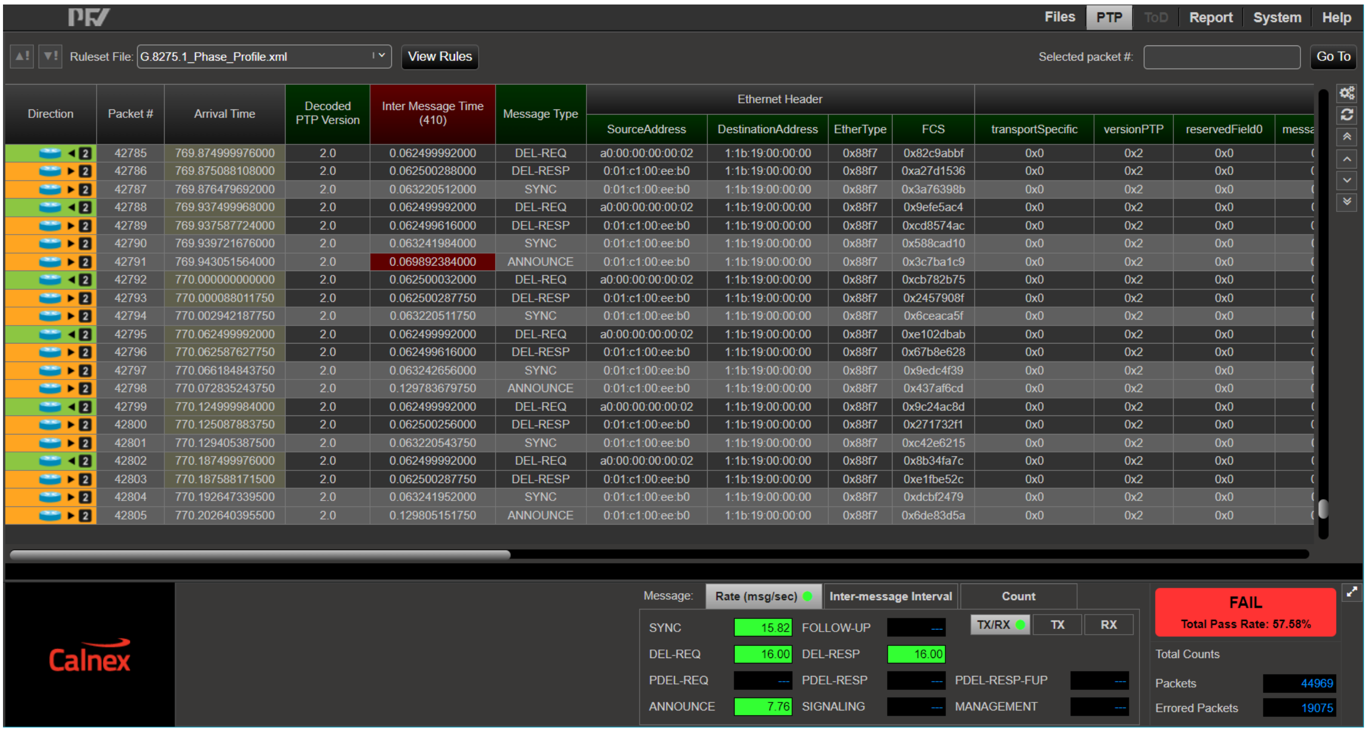
Follow the steps in Section 7.4 of this document using the imported PTP impairment pattern instead of the built-in pattern, optionally applying SyncE wander if desired.

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**.



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 (Max|TE_L|)	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 (Max|FE|)	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.**

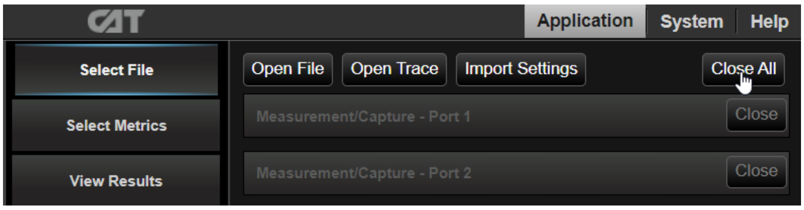
8.2. Performance Test: O-DU with Embedded GNSS Receiver

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

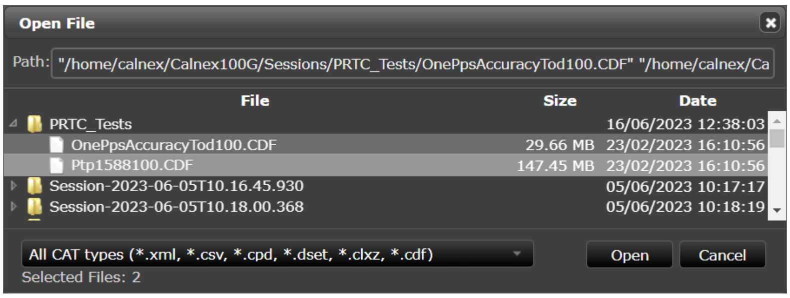
1. From the Paragon Neo **Application** interface, launch the **CAT** application by clicking on any **CAT** button:

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.



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).

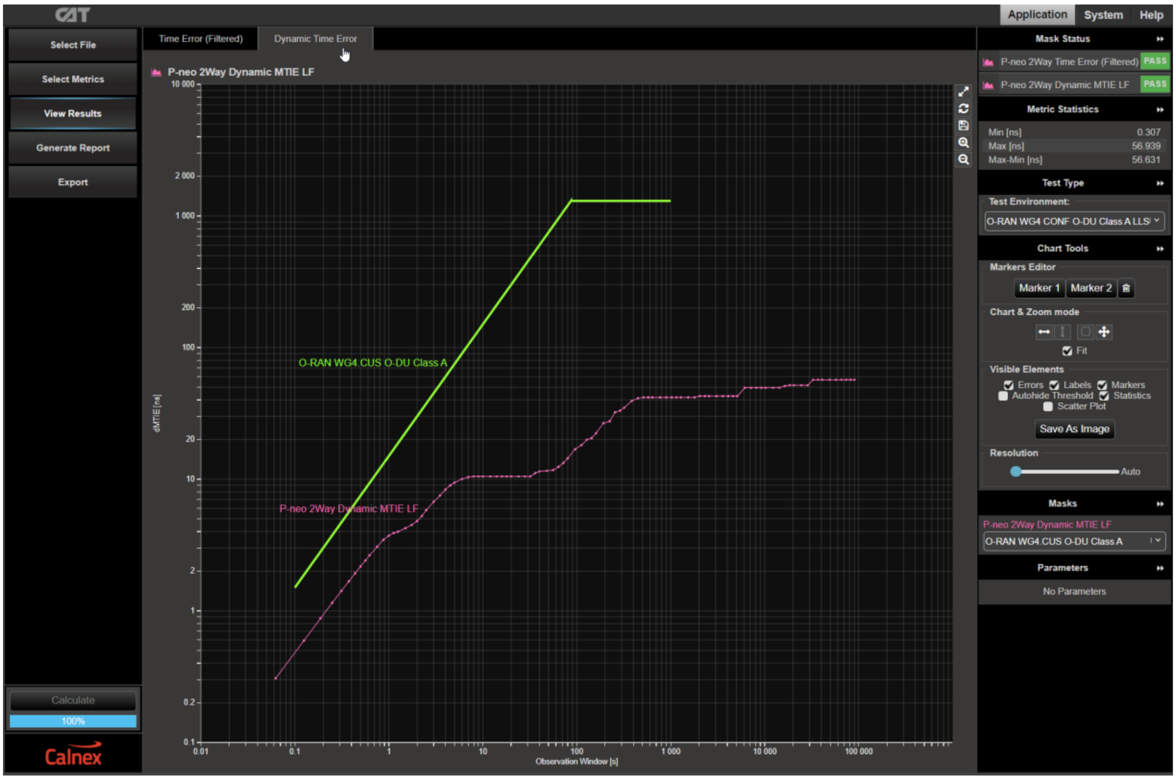


5. When the files have loaded, click **View Results,** the measurements will be displayed with the default metrics applied.

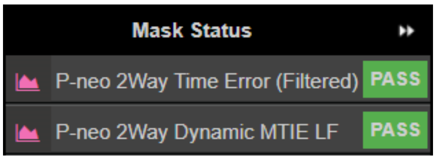
6. The **Test Environment** function automatically configures the displayed metrics, masks, and thresholds to a range of preset values such as those required for testing compliance to device or network standards.

7. Select the appropriate **Test Environment** for the current test and O-DU type.

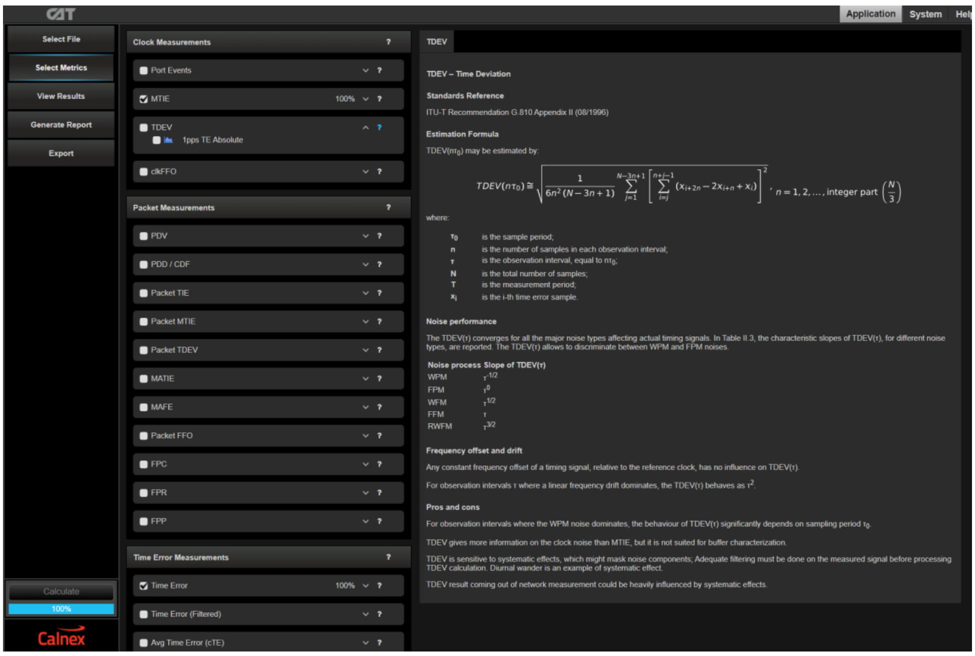
8. Navigate to the available metrics for the Test Environment by using the tabs at the top of the window.



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.



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