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PTP Testing with xGenius: Dual PTP Analysis Test

The ALBEDO xGenius are equipped with advanced synchronization testing capabilities including support for legacy and packet synchronization technologies. Among the latter the most important is the *Precision Time Protocol* (PTP) which has been successfully used to provide accurate timing to cellular networks, power substations and large factories.

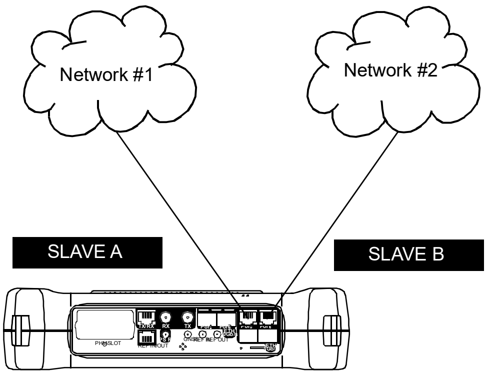

Figure 1 *The xGenius .Dual sync analyser mode measures PTP performance in two links at the same time*

xGenius has the ability to simulate PTP masters and slaves and run different kinds of test to verify the operation of PTP entities deployed in a communication network at different levels ranging from protocol decoding and capture, statistics collection and performance analysis. One of the outstanding advantages of this testing tool is to simulate different PTP entities at the same time by taking advantage of multi-port configurations. This note deals about one of these multi-port configurations that enables the unit to simulate two PTP slaves at the same time running in two physically different Ethernet ports. In the xGenius terminology, this operation mode is known as *Dual Sync Analyzer*. Users are allowed to configure the same or different profiles in each of the test ports, collect statistics from each slave and get the timing performance results from each of them including time and frequency offset.

The obvious advantage of running two PTP tests in one tester is to save time. With the help of the Dual Sync Analyzer mode, users are allowed to run two tests in the same time needed to run a single test in an analyzer equipped with only one port. There are, however, more subtle and important advantages related with applications where correlation between two different PTP references is to be measured. Two of these applications are described here: (1) 5G synchronization when coordinated transmission or reception from multiple points such as *Multiple Input, Multiple Output* (MIMO) is used, (2) PTP distribution over the IEC 62439-3 *Parallel Redundancy Protocol* (PRP), which is important for power utility applications.

1. LTE / 5G synchronization

Timing in cellular networks and specifically in networks based LTE and 5G technology is required for two different reasons: (1) There is an inherent timing and synchronization need in 5G to avoid interferences between nearby base stations and *User Equipments* (UEs). (2) Some services deployed over the cellular network have strict timing requirements. These include positioning, industrial automation or Smart Grid applications.

Connected with the 5G timing requirements, we also have two separated classes. At one hand, he have the *Time-Division Duplexing (TDD)* requirements which are set for both LTE-TDD and 5G to a maximum time offset of 1.5 µs from UTC. But on the other hand, there are requirements related to link aggregation, transmission diversity and MIMO.

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Table 1
LTE and 5G cluster limits in terms of TAE

Metric	*LTE*	*5G*
Inter-band carrier aggregation	*260 ns*	*3 µs*
Intra-band non-contiguous carrier aggregation	*260 ns*	*3 µs / 260 ns*
Intra-band contiguous carrier aggregation	*130 ns*	*260 ns / 130 ns*
MIMO or TX diversity transmissions, at each carrier frequency	*65 ns*	*65 ns*

These technologies have the common feature that they allow for an increase in transmission bandwidth, throughput or efficiency by a coordinated use of multiple transmitters or receivers. For these technologies there is no need for global (UTC) timing requirements but there is often an strict limit for the interrelated elements belonging to the same cluster. Cluster limits are defined in terms of the relative time offset between the members of the same cluster rather than with the comparison to an absolute time reference such as UTC or TAI.

If the time offset from the cluster members to UTC is known we can also compute any required relative metric, but the accuracy of relative time error measurements is often better than for absolute time error. That means that any result derived from absolute time error are not going to have the same accuracy than direct relative measurement. An additional advantage of the relative time error results is that they can be obtained without an external reference such as GNSS.

Unfortunately, relative time offset tests are only possible in lab environments or where the equipments to be verified are co-located. However, many times this is precisely the case when cluster measurements are required. For this reason, a testing tool like xGenius is useful both for laboratory and field measurements of relative time error.

2. PTP over PRP

The *Parallel Redundancy Protocol* (PRP) provides failsafe operation in a LAN by duplicating the transmission media. Every piece of information is transmitted twice over mutually isolated networks (LAN A and LAN B). If one of the replicas is lost, it is very likely that the the information is still received through the alternative channel. In normal operation conditions, frames are received twice and *Doubly Attached Nodes* (DANs) implement a duplication detection algorithm designed to drop most duplicated frames before they are processed by higher protocol layers.

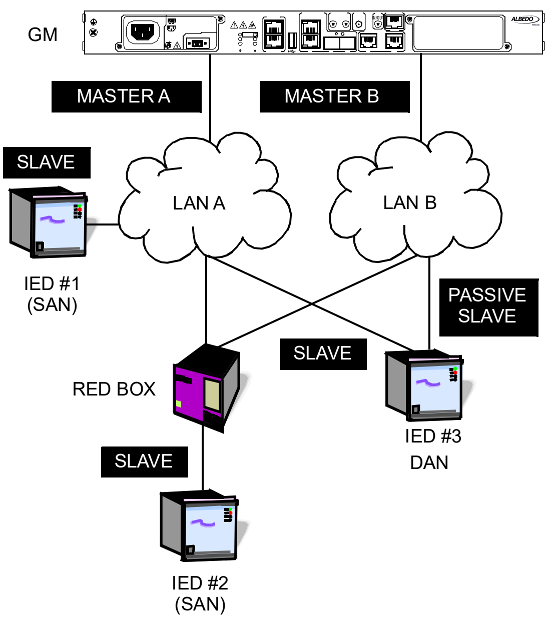

Figure 2 *PRP provides redundant communications to IED #2 and #3. IED#1 is sensitive to network faults.*

The PRP standard is flexible enough to accept interoperability with nodes connected to only LAN A or LAN B. These are called *Singly Attached Nodes* (SANs). There are no strict requirements for LAN A and LAN B. These are typically bridged Ethernet networks designed so that a failure event in one of them does not affect the second network.

Timing distribution in PRP networks is a challenge because timing information is collected from two channels with two delay paths. This fact makes delay compensation unfeasible. At some point, the slave could be applying a compensation derived for LAN A in a Sync packet received in Port B. The solution to this issue is addressed in IEC 61850-9-3, the PTP Utility Profile: A DAN operating in PTP slave mode will keep only one of the ports in SLAVE state while the other remains in PASSIVE SLAVE mode. PASSIVE SLAVE and SLAVE ports are similar but PASSIVE SLAVE ports do not discipline the oscillator unless a fault is detected in the SLAVE port. In that case the PASSIVE SLAVE port becomes a regular

SLAVE port. With this procedure, consistency between PTP synchronization (Sync message flow) and delay compensation (Peer Delay Request / Response flows) procedures is guaranteed.

The ALBEDO xGenius test unit has the ability to run simultaneous PTP tests the the PRP LAN A and B to check that performance limits are met in both LAN, the active and the passive ones.

Table 2
IEC 61850-9-3 performance limits

Device	*Metric*	*Value*
Grandmaster	*Inaccuracy*	*250 ns*
Transparent clock	*Inaccuracy*	*50 ns*
Boundary clock	*Inaccuracy*	*200 ns*
Media converter	*Asymmetry*	*25 ns*
Links	*Asymmetry*	*25 ns*

In accordance with standard IEC 61850-9-3, it should be possible to achieve an end-to-end tining performance better than 1 µs in the substation network. Relative time error measurements help network administrators to detect a time skew generated by the GM or by asymmetric delay in the network.

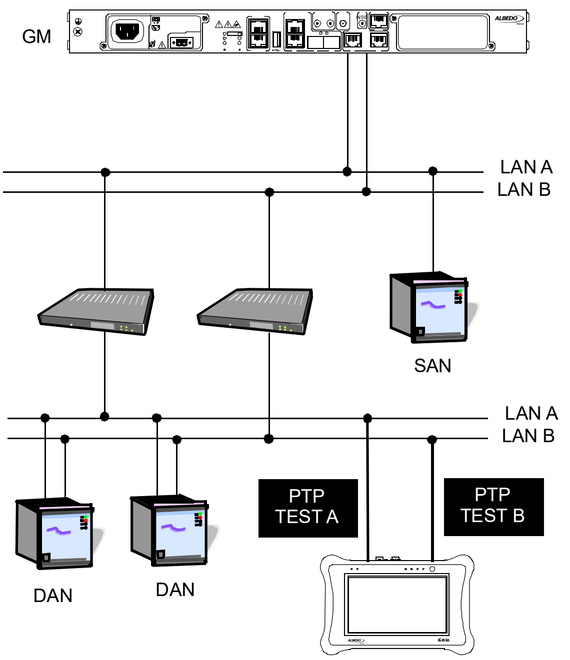

Figure 3 *xGenius runs two simultaneous PTP tests and rates the transmission performance of LAN A and B.*

PTP performance measurements can be combined with customized background traffic generation. This approach enables users to study how the performance is degraded as the traffic load increases.

3. Running the Test

The following paragraphs describe the *Dual Sync Analyzer* test in xGenius. The testing procedure admits many small variations. In the setup described here it is considered that the test interface is RJ-45 without VLANs tags. PTP utility profile IEC 61850-9-3 is set in both test ports.

Setting up the Reference

xGenius may be equipped with a built in GNSS receiver. These units have a SMA female connector suitable for connecting an antenna. Units with the built in GNSS receiver are also supplied with a compact antenna with 5 m of coaxial cable plus a 10 m extension cable. Using a different antenna is possible as long as the specifications of the GNSS module are taken into account.

To use the built in GNSS module follow these steps:

1. Attach the antenna to the unit. Make sure that the antenna sees as much of the sky as possible. The unit may fail to achieve synchronization if there are not enough satellites in sight. Some tests may loss accuracy if the number of satellites in sight is reduced.
2. From the *Home* panel, go to *Config*, The port setup panel is displayed.
3. Go to *Reference clock*.
4. Configure *Input clock* to *GNSS*.
5. Press *LEDS* to display the test status.
6. Wait for the REF and LOCK LEDs to become green.
   Note: The locking process for the OCXO version of xGenius may take around 10 minutes. The coarse locking process in Rubidium units requires around 20 minutes.
   Note: Both Rubidium and OCXO versions of xGenius are ready for testing once the LOCK LED is green but Rubidium units are not yet prepared to supply their maximum accuracy.

These units go to a *Fine locking* status before being fully *Locked* to the reference. The *Fine locking* status may last for around four hours in Rubidium units. OXCO units do not have fine locking status and they go directly to the *Locked* when they finish the coarse locking procedure. The user could check the current locking status (*Locking*, *Fine locking*, *Locked*, *Holdover*, etc.) from the *Oscillator* menu in the *Reference clock* menu.

Configuring the GNSS Properties

The user could optionally configure the GNSS interface in the test unit. Despite being not mandatory, the increase in accuracy it could be obtained in this way is quite important. This is the required procedure:

1. From the *Home* panel, go to *Config*,
   The port setup panel is displayed.
2. Go to *Reference clock*.
3. Go to *GNSS receiver*.
4. Configure a compensation for the antenna cable through the *Antenna delay correction* field.
5. Enable or disable any of the *GPS*, *GLONASS*, *Beidou* or *Galileo* constellations through the *Active GNSS* setting.
6. Go to *Fixed-position mode*.
7. Adjust the *Position averaging time* and enable position averaging by configuring *Fixed-position mode* to *Auto-average*.
   The *Fixed-position status* field now displays *Averaging*
   Note: At least one hour of position averaging is required for a reasonable accuracy.
   Note: The position averaging procedure should run only once as long as the test unit geographical location is not changed. The unit checks any change in position (longitude, latitude, altitude) every time it is connected to a GPS antenna. If a change in the coordinates is detected, then an error message is displayed in the status field and the mode is disabled.
8. Wait to the *Fixed position status* to become *Active*. The unit is now ready for testing.
   Note: Theoretically, testing could start before the end of the position averaging process. The improved time estimation due to this function would be automatically applied starting from the end of the auto-averaging process.

Configuring the Dual Sync Analyzer

xGenius Port A and Port B in the same unit can be configured to become a PTP pseudo-slave with the ability to compare the input phase between them or with the tester own internal time and generate miscellaneous performance parameters, including relative and absolute TE results.

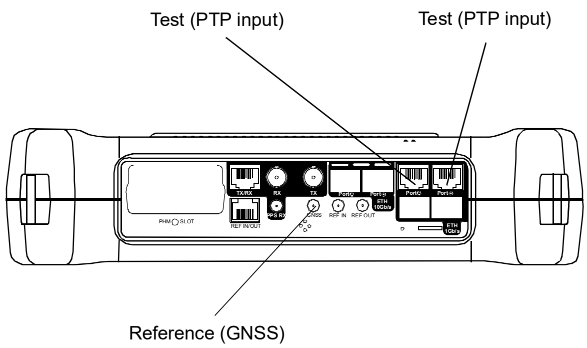

Figure 4 *Albedo xGenius test and clock reference interfaces used in this testing scenario.*

Connecting the Unit

This scenario assumes that the test interfaces are electrical. Connect the Port A RJ-45 connector to the PRP LAN A and Port B RJ-45 connector to the LAN B.

1. From the *Home* panel, go to *Config*,
   The port configuration panel is displayed.
2. Select *Mode* to enter in the mode selection menu.
3. Choose *Ethernet endpoint*.

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Enabling the Test

xGenius includes different test options for PTP. Here we are interested in the test option for BCs and TCs. Follow these steps to enable the required test mode:

1. From the *Home* panel, go to *Test*.
   The test configuration panel is displayed.
2. Go to *PTP*.
3. Configure *PTP mode* to *Dual sync analyzer*.
   Two labels are displayed in the top notification area. The former (*PTP*) shows that PTP is enabled in the unit, the latter (*SS*) shows that the unit is emulating two PTP slaves at the same time.

Configuring LAN A PTP Pseudo slave

The following sequence is required to generate the PTP stimulus signal in Port A. It is assumed that the port is running the ITU-T G.8275.1 profile:

1. From the *Home* panel, go to *Test*,
   The test configuration panel is displayed.
2. Go to *PTP*.
3. Go to *Slave clock A* settings
4. Configure *Addressing mode* to *Multicast* and *Path delay mechanism* to *Peer-to peer*.
5. Configure the timing of the different messages associated to PTP from the *Message timing* menu: *Sync TX interval* must be set to *1 pkt/s*, *Peer Delay Request TX interval* to *1 pkt/s*, *Announce TX interval* to *1 pkt/s*, *Announce RX timeout (#msgs)* to *3*.
6. Configure the *Domain* to the right value for your network.

Configuring the LAN B PTP Pseudo-slave

To configure the LAN B analyzer, proceed in the same way that in *Port A* but use the *Slave clock B settings* menu rather than *Slave clock A settings*.

If the Port A and Port B settings are correct, the PTP indications (*PTP SS*) in the top of the screen will change from yellow to green.

Configuring the Test Thresholds

Once the PTP is active the user still has to configure the tests to be run and set the thresholds for the results. In this setup we only need to configure the TE thresholds. No specific action is required to enable the TE test but the TE thresholds must be set by means the following procedure:

1. From the *Home* panel, go to *Test*,
   The test configuration panel is displayed.
2. Go to *PTP two way TE objectives*.
3. Configure *Enable* to *On*.
4. Set *Total peak* to *1* µs.
5. Set to zero all the remaining parameters in the PTP two way TE objectives panel.

Running the Test

Te test is now ready to start. Press *RUN* in the test unit to do that. Now the TE metrics are computed in real time. To check the TE results follow these steps:

1. From the *Home* panel, go to *Results*,
   The test port results panel is displayed.
2. Select *Port A* to enter in the port specific results.
3. Enter in *PTP* to display results about the PTP protocol.
4. Go to *Time Error statistics* to get the 2-way TE results.
5. Check the maximum and minimum values of *Total* and *Relative* TE and check that these are under the limits defined by IEC 61850-9-3.

To check the LAN B results repeat the previous steps in the *Port B* results menu. To stop the TE test press *RUN* a second time at any moment.