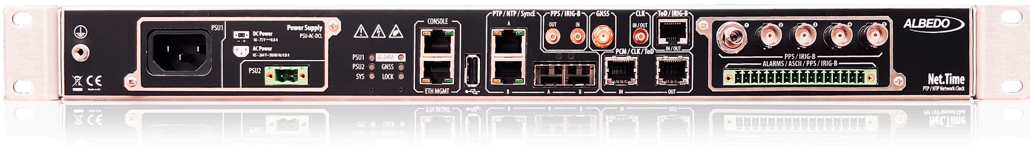

Net.Time: Using the Time Holdover Function

Clock references are typically classified in two families, frequency and time. While frequency references are highly accurate they lack of the information required to determine the time in a given timescale. This property limits the application of frequency references where availability of UTC or TAI time is important.

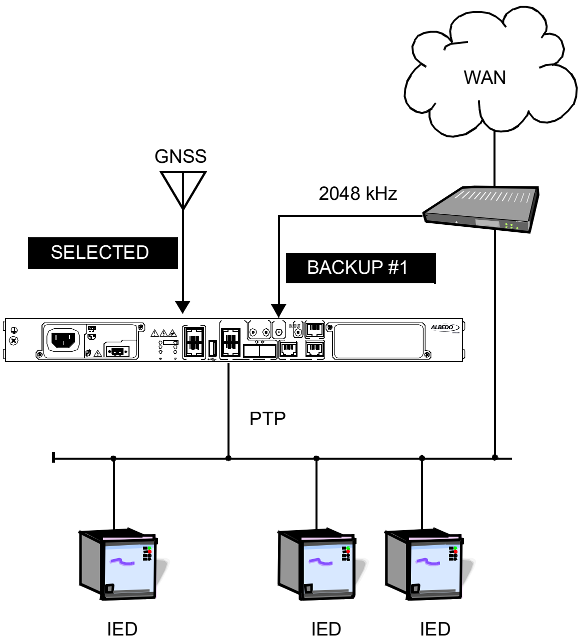

Figure 1 *Using a frequency backup. The backup clock reference is derived from the WAN.*

From the previous paragraph we could conclude that frequency references are not useful in time distribution deployments but this is not truth. Frequency references are still very useful in many scenarios. One interesting approach is to derive the frequency in a device or system from a frequency reference (Synchronous Ethernet, for example) and to use a time reference to set the time. PTP or GNSS could be used for this purpose. This document deals about a second interesting application based on using a frequency reference to extend the holdover period of a network clock. The most typical example of this is a clock with unstable GNSS reception due to la weak signal, intentional jamming or other reason. Clocks equipped with OCXOs may generate a phase error of tens of microseconds per day which is out of the specification of several important timing applications. If a frequency reference is available, it can be useful to keep the stability of the OCXO in periods where the GNSS reference is lost. The performance level it can be achieved with this technique depends on the how accurate is the backup frequency reference but it should be possible to extend the holdover for periods of several weeks with an error level of less than one microsecond.

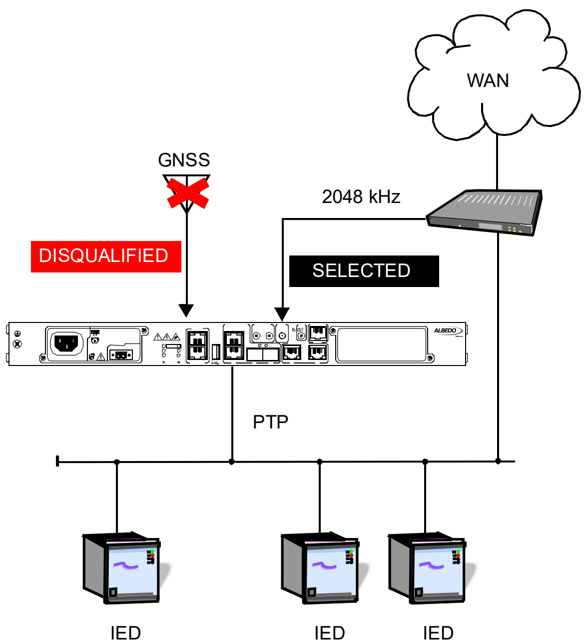

Figure 2 *If the main reference is lost, the backup is selected.*

One of the advantages of this approach is that frequency references are often readily available. For example, SDH / SONET networks are themselves synchronous and an accurate frequency of 2048 kHz

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or 1544 kHz can be derived from the network interface. In more modern deployments based on Ethernet and MPLS-TP there is still the possibility to propagate an accurate frequency through the network with Synchronous Ethernet.

1. Setting up Main Reference

In this note we will consider that the main reference is GPS but other alternatives are possible and interesting. One of them is to use a PTP main reference and a frequency backup, maybe Synchronous Ethernet. It is assumed that the Net.Time unit is restored to its factory values before starting the configuration and the following configuration is set in the unit:

- The device host name is set to “nettime”. The domain name “nettime” is also assigned to the clock.
- SSH management is enabled.

These are the steps to follow to enable and configure the GNSS reference in the unit using the CLI:

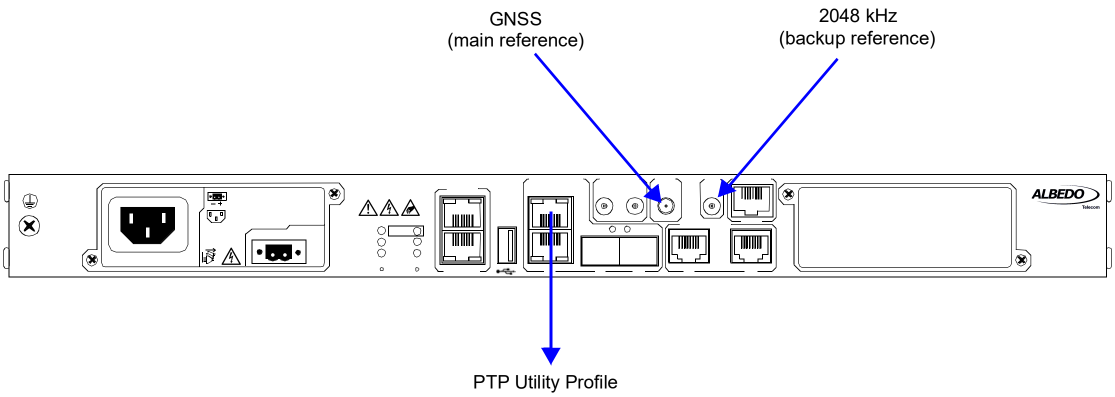

Figure 3 *.Location of GNSS and 2048 clock reference inputs and PTP clock reference output used in this application.*

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 on sight.
   Details about how to install the antenna are omitted in this document and it is assumed that installation tasks are finished.
2. Log in the system using SSH and a controller account

```
ssh ctrl@nettime
ctrl@172.26.4.182's password:
```

3. Map the GNSS interface to the GNSS input

```
ctrl@nettime> set map GNSS(G) add gnss01
```

   The locking process to the GNSS reference starts.

4. Optionally, enable the fixed position mode to improve the time accuracy

```
ctrl@nettime> set input gnss gnss01 fixed-position mode enable
```

   If the Net.Time unit doesn’t have a stored position, then it will retrieve its latitude, longitude and ellipsoidal height coordinates by means an averaging process that lasts for 24 hours in the default configuration. Fixed position mode will start at the end of this averaging process.

5. Wait for the locking process to finish. You can optionally display the oscillator sync status with

```
ctrl@nettime> show oscillator

Oscillator sync status
--------------------------------------------------
Oscillator type:                             OCXOE
Oscillator lock status:                Time synced
Elapsed time:                           0/00:06:25
Holdover remaining time:                         -
```

6. Optionally, provision the GNSS input with

```
ctrl@nettime> set admin-status GNSS(G) provision
```

This action locks the configuration to avoid unwanted port misconfiguration in the future

2. CONFIGURING THE BACKUP

The backup reference is an unbalanced 2048 kHz input. For optimum performance, the reference should be traceable to a primary frequency source. Configuration of a backup reference based on a different frequency (1544 kHz, 10 MHz, etc.) is equivalent. The steps to follow to configure the reference are described below:

1. Map the frequency (*clk*) interface to the coaxial input

```
ctrl@nettime> set map SMB(H) add clk04
```

2. Set the interface frequency

```
ctrl@nettime> set input clk clk04 signal-type freq2048khz
```

3. Assign a *PRC* default quality level to the interface

```
ctrl@nettime> set input clk clk04 default-ql prc
```

4. Optionally, display the reference hierarchy to make sure that clock references are properly configured:

```
ctrl@nettime> show ref

Interface   Type      Priority   Input QL                          Reference status
-----------------------------------------------------------------------------------------
gnss01      time      2          PRTC                                      selected
clk04       frequency 2          PRC                            qualified (backup #1)

Reference mode          : time
Reference source        : SSM
```

5. Optionally, provision the SMB unbalanced input with

```
ctrl@nettime> set admin-status SMB(H) provision
```

In the previous procedure, it may not be evident why the interface *clk04* must be mapped to *SMB(H)*. Information about the port to be used in the mapping is given by the following command:

```
ctrl@nettime> show map ports
Port            Label                     Interface                 Admin Status
--------------------------------------------------------------------------------
ETH(A)          PTP/NTP/SyncE, A          none                            config
ETH(B)          PTP/NTP/SyncE, B          synce03                         config
RJ48(C)         PCM/CLK/ToD IN            none                            config
RJ48(D)         PCM/CLK/ToD OUT           none                            config
SMB(E)          PPS/IRIG-B OUT            none                            config
SMB(F)          PPS/IRIG-B IN             none                            config
GNSS(G)         GNSS                      gnss01                       provision
SMB(H)          CLK IN/OUT                none                            config
RJ48(I)         ToD/IRIG-B IN/OUT         none                            config
```

In the previous table, the label matches the text printed in the Net.Time front panel. This is the text that provides simple port identification in the unit but we still don't know which frequency interface is to be mapped to the port. The answer is provided by the following command:

```
ctrl@nettime> show map SMB(H) reachable-interfaces
Port            Interface                                    Reachable interfaces
--------------------------------------------------------------------------------
SMB(H)          none                                                 clk04, clk03
```

In the previous case, is still unclear whether to use clk03 or clk04 in the mapping. The next command provides the final answer:

```
ctrl@ntime03> show interfaces
Interface               Input/Output        State                    Signal type
--------------------------------------------------------------------------------
gnss01                  input               selected                           -
clk01                   output              idle                               -
clk02                   input               idle                               -
clk03                   output              idle                               -
clk04                   input               idle                               -
tod01                   output              idle                               -
tod02                   input               idle                               -
tod03                   output              idle                               -
tod04                   input               idle                               -
pps01                   output              idle                               -
pps02                   input               idle                               -
ntp01                   output              idle                               -
ntp03                   output              idle                               -
irig01                  output              idle                     pulse-width
irig02                  input               idle                     pulse-width
pcm01                   output              idle                               -
pcm02                   input               idle                               -
ptp01                   output              idle                               -
ptp03                   output              idle                               -
synce01                 output              idle                               -
synce03                 output              ready                              -
```

We can now see that *clk03* is an output and it is therefore not useful for us. The correct interface is then *clk04* which is an output, as required.

3. Enabling the PTP server

Once the clock inputs are ready we still need to configure the PTP output to provide accurate timing to the IEDs deployed in the substation. We will assume that these IEDs are compatible with the standard IEC 61850-9-3, which describes the PTP Utility profile.

1. Map the PTP (*ptp*) output interface to one of the Ethernet ports

```
ctrl@nettime> set map ETH(A) add ptp01
```

2. Provide an IP address (assumed here 10.0.0.1) to the ETH(A) port with

```
ctrl@nettime> set network ETH(A) address 10.0.0.1
```

3. Provide a subnet mask (assumed 255.0.0.0) to ETH(A)

```
ctrl@nettime> set network ETH(A) netmask 255.0.0.0
```

   This and the previous steps are not strictly necessary when the PTP profile is going to be the Utility profile but it is still useful to avoid the INIP alarm and to allow the port to be reached by ping.

4. Configure the Utility profile in ETH(A)

```
ctrl@nettime> set output ptp ptp01 profile utility
```

5. Optionally, verify the PTP output

```
ctrl@nettime> show ptp ptp01 status
ptp01 current status
----------------------------------------------------------------------
Status:                                                          ready
Clock state:                                                   started
Port0 state:                                                    master
Current clockClass:                                                  6
Master IP address:                                                   -
Master Ethernet address:                                             -
Master identity:                                0O:DB:1E:FF:FE:00:0E:1E
Master port number:                                                  0
Timescale:                                                         TAI
Grandmaster identity:                           00:DB:1E:FF:FE:00:0E:1E
Grandmaster priority 1:                                            128
Grandmaster priority 2:                                            128
Grandmaster clock class:                                             6
Grandmaster clock class desc:                       Synchronized to PRC
Grandmaster clock accuracy:                                 1.00e-07 s
Grandmaster clock variance:                                          -
Grandmaster time source:                                           GPS
```

6. Optionally, provision the Ethernet output with

```
ctrl@nettime> set admin-status ETH(A) provision
```

At this point, the unit will start distributing time in the Ethernet network through the PTP protocol. If the oscillator has already finished the locking process the IEDs will receive accurate timing from the clock.

4. Performance Results

The time holdover function has the ability to keep good performance level even in long periods without the main reference, GNSS in our setup. To verify this point we manually disconnect the GNSS antenna from the unit to force a switchover to the 2048 kHz backup input. Then, with the help of a synchronization tester, we measure *Time Error* (TE) in the PTP output.

To make sure that the unit is now in holdover we use the following command:

```
admin@nettime# show oscillator

Oscillator sync status
--------------------------------------------------
Oscillator type:                            OCXOE
Oscillator lock status:             Time holdover
Elapsed time:                           0/00:04:11

Holdover remaining time:                9/23:55:49
```

If we display the reference hierarchy now, we find the following expected result:

```
admin@nettime# show ref
Interface   Type       Priority    Input QL                                  Reference status
-----------------------------------------------------------------------------------------------
clk04       frequency 2            PRC                                               selected
gnss01      time       2           DNU                                           disqualified

Reference mode            : time
Reference source          : SSM
```

Results show that time holdover performance is nearly the same that the locked performance when the testing period is three days. This result is compared with a frequency holdover for the same period. The TE results after three days is close to four microseconds for the frequency holdover but it stays within a range of a few tens of nanoseconds in the time holdover scenario. In our setup, the 2048 kHz reference, and the test unit, were locked to GNSS. This factor explains the excellent results. If the frequency reference was not traceable to GNSS but to a different primary source, the results would probably be slightly worse. The TE performance in this case would be given by the frequency offset in the 2048 kHz signal.

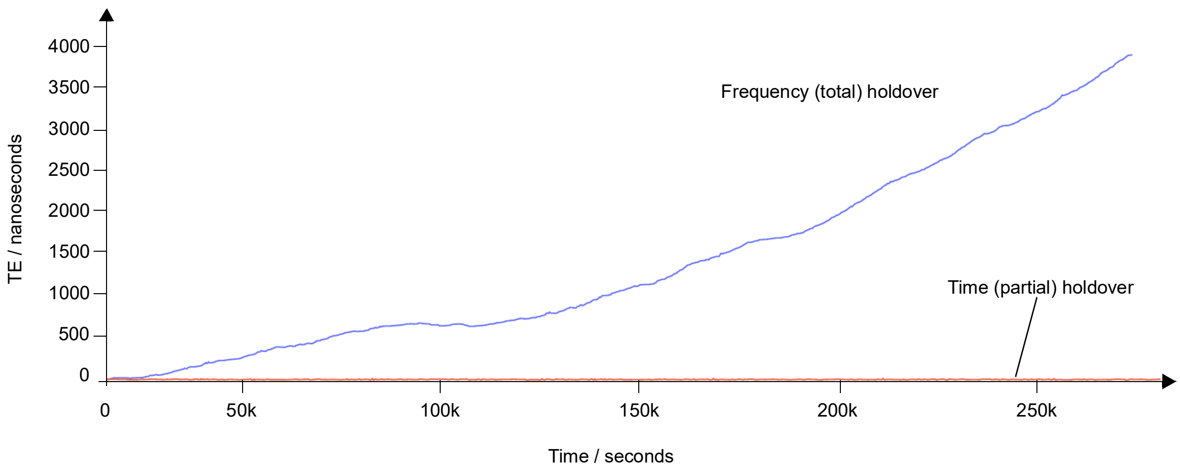

Figure 4 *Frequency and time holdover performance for a holdover period of three days.*