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Are the current PTP profiles ready for a robust phase-delivery network?

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What do we mean by a robust network?

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A robust phase-delivery network needs to:

- **deliver required phase accuracy and phase stability under nominal conditions**
- **maintain that phase accuracy and stability under most abnormal conditions**
- **report when it can no longer meet the requirements**

What are the most-likely abnormal conditions?

- **Loss of timing path**
  - failure of any equipment in the timing path
  - failure of any communication path between equipment in the timing path
- **Excessive noise in timing path**
  - Higher than normal PDV
  - Large phase transients on physical-layer clocks
  - Degradation of GNSS
- **Loss of timing reference into the timing path**
  - e.g., loss of GNSS

Review of G.8265.1

- **G.8265.1: intended for frequency-delivery on existing networks**
  - Profile is complete and widely deployed
  - Frequency accuracy and stability defined in G.8261.1 (note, no intention to put any ultimate limit on phase).

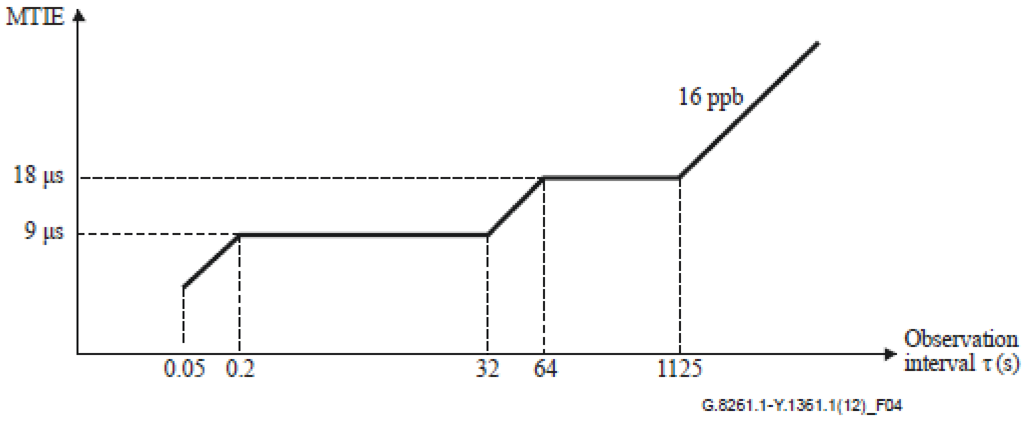
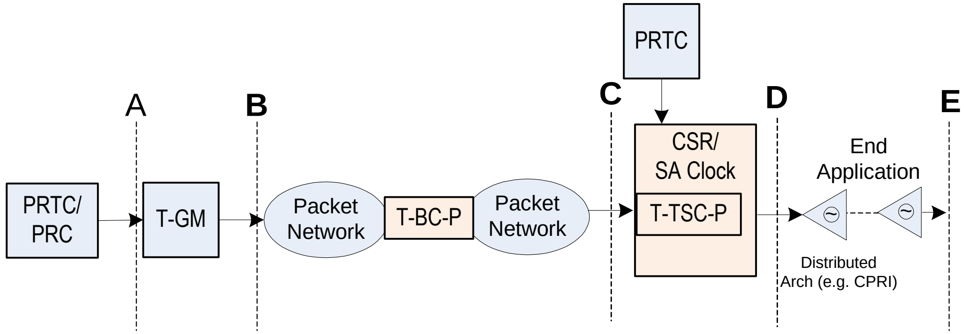


Figure 4 – Output wander network limit for case 3 based on [ITU-T G.823]

Review of G.8275.2

- **G.8275.2: intended for existing networks where only partial support can be provided**
  - Profile development just started
  - Initial goal is to provide mutual assistance between GPS at cell site and PTP flow from remote GPS receiver (PRTC) to obtain microsecond-level holdover drift over 72 hours.



Taken from WD44/ITU-SG15-Q13 Kansas interim meeting (Sprint et al)

Review of G.8275.1

- **G.8275.1: intended for new networks where full timing support can be provided by all equipment throughout the timing path**
  - Profile is almost complete
  - Many vendors have equipment to suit
  - Phase accuracy and stability tightly controlled:

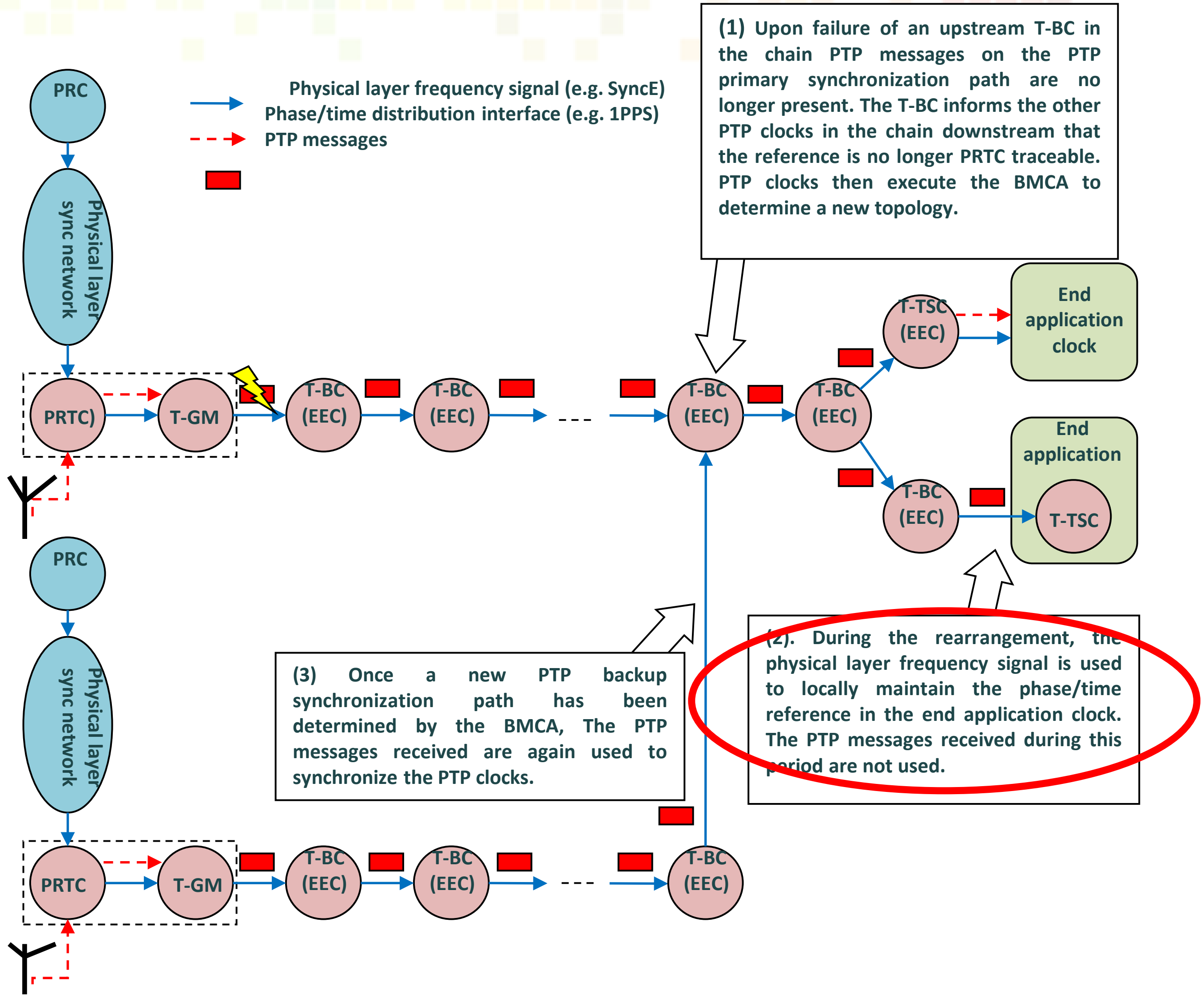
Budget Component	Failure scenario a)	Failure scenario b)	Long Holdover periods (e.g. 1 day)
PRTC (ce_{ref})	100 ns	100 ns	100 ns
Holdover and Rearrangements in the network (TE_{HO})	NA	400 ns	2400 ns
Random error due to synchronous Ethernet rearrangements (dTE')	200 ns	200 ns	200 ns
Node Constant including intrasite (ce_{ptp_clock}) (Note1)	550 ns	550 ns	550 ns
Link Asymmetries (ce_{link_asym}) (Note2)	250 ns	100 ns	100 ns
Rearrangements and short Holdover in the End Application (TE_{REA})	250 ns	NA	NA
End application (TE_{EA})	150 ns	150 ns	150 ns
Total (TE_D)	1500 ns	1500 ns	3500 ns (Note3)

G.8271.1/Table VI.1 – Example of Time Error allocation (in network limit)

Full-support performance limits:

- ❑ Switch-over to redundant timing paths takes time, needs time-holdover to contain phase drift
- ❑ Normal operation and time-holdover relies on clean operation of SyncE
- ❑ Generally relies on GNSS performance

Switch-over takes time:



Transient performance depends on time-holdover (i.e., SyncE)

Weaknesses in SyncE?

SyncE works very well in practice (good clock designs), but….

- ❑ **G.8262 was developed very quickly**
- ❑ **It was heavily based on previous ITU recommendations (G.812, G.813, G.823/4/5, G.781)**
  - It retained the MTIE/TDEV masks for noise-generation and noise transfer.

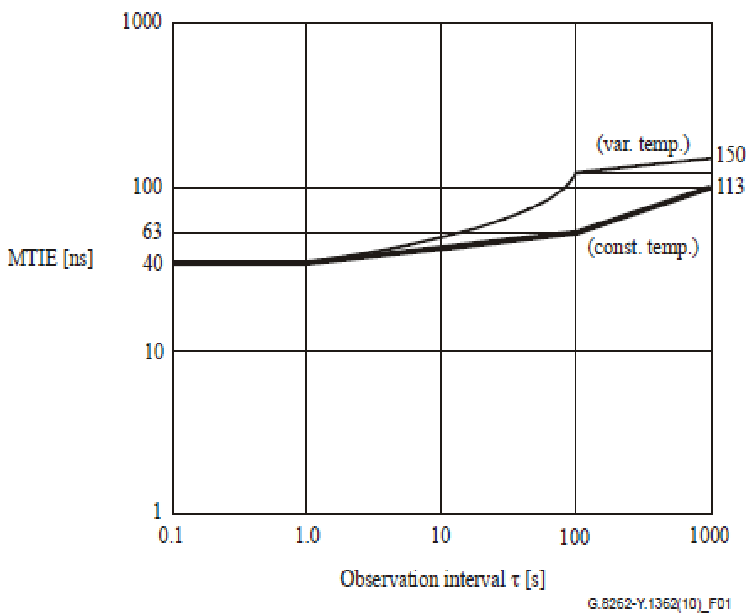


Figure 1 – Wander generation (MTIE) for EEC-Option 1

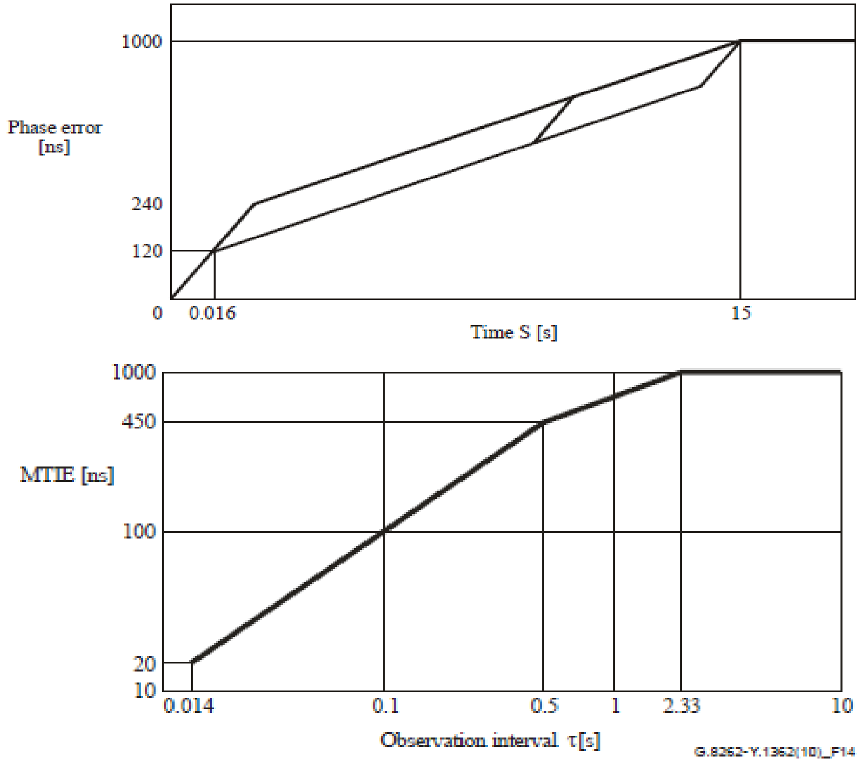


Figure 14 – MTIE at the output due to reference switching/ rearrangement operations for EEC-Option 2

Weaknesses in SyncE? (cont.)

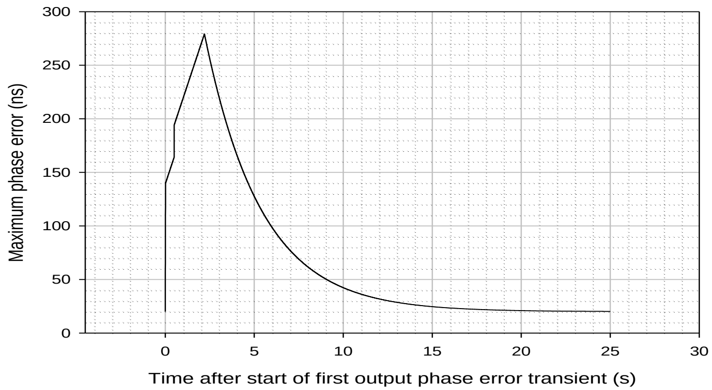
Simulations show that phase transients on SyncE can significantly affect time-delivery performance of the packet layer, and seriously restrict performance of time-holdover operation.

- **Note that these are only potential problems. They appear because the noise levels and the amplitudes of phase transients used in the simulations are allowed by current standards.**
- **Real-world experience shows that modern equipment provides much better performance.**
- **But the risk is still there that lower-quality equipment could limit achievable performance**

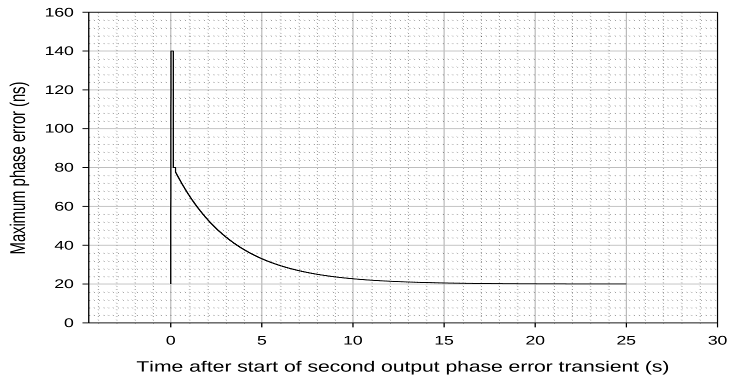
We could look at tightening up the standards to prevent poor-quality designs.

Why not add a new clock type that reflects current performance in terms of noise and switching transients?

T-BC output phase mask for first output phase error transient after start of SyncE rearrangement



T-BC output phase mask for second output phase error transient after start of SyncE rearrangement



Note: Masks only apply to Option 1. Option 2 transients are too fast to catch.

Problems caused by reliance on GNSS:

Not all GNSS problems are easy to detect

- **In particular, GNSS spoofing is hard to detect**
  - Spoofing can gradually distort the timing of a base station, causing it to interfere with neighbours before the problem can be detected.

Needs a solution which is independent of GNSS, such as providing back-up timing paths for majority voting.

What can we do to remove these limitations?

- **Reliance on time-holdover during switch-over needs clean physical-layer clocks**

  Enhance current standards to ensure current real-world performance is maintained.

  “Normal” holdover could be avoided if a back-up timing path is available for instant use.

- **Some GNSS problems cannot be detected quickly enough to avoid performance hit**

  Multiple back-up timing paths could allow majority voting.

  Alternative time-distribution mechanisms could be used to back-up GNSS

Deploying Back-up Timing Paths:

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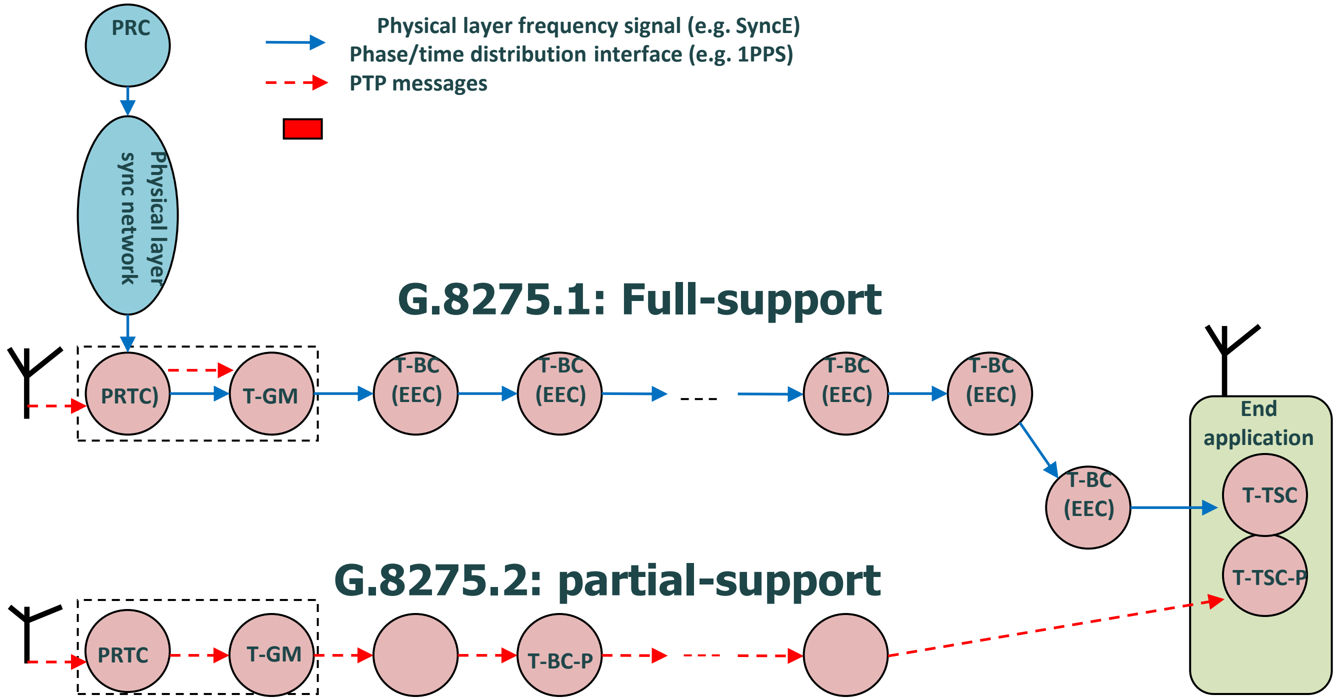
The drive behind G.8275.1 is to provide microsecond-level accuracy to wireless basestations. Holdover for significant periods needs expensive local oscillators.

The drive behind G.8275.2 is to use PTP to provide holdover assistance when local GNSS receiver fails to deliver microsecond-level accuracy to wireless basestations.

So why not deploy both profiles to back up each other?

This would also allow majority voting to detect GNSS spoofing (see the follow-on presentation in Session 7)

Deploying both G.8275.1 and G.8275.2, (and/or end-point GNSS)

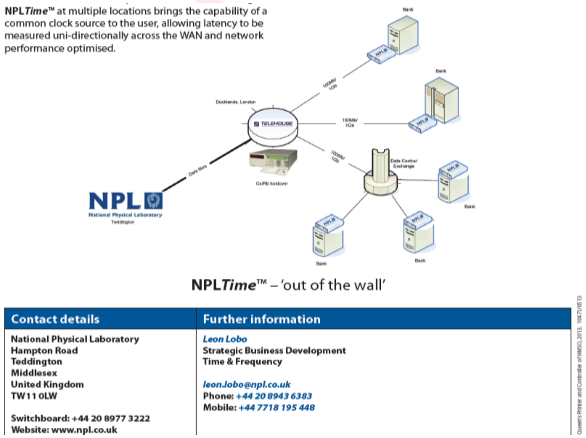


Partial-support path provides:

- instant recovery in case of loss of full-support path.
- Third vote for majority-voting scheme

Back-up GNSS by using alternative time-distribution mechanisms:

- **E.g., NPL*Time*™, which provides UTC(NPL) over dark fibre**



- **Or, e.g., LOFAR (Low Frequency Array), which achieves nanosecond-level time-distribution across Europe using two-way, common-view GPS satellite time-transfer.**

To easily use these mechanisms needs a common interface into the T-GM…..

Let's look at the interface into the T-GM:

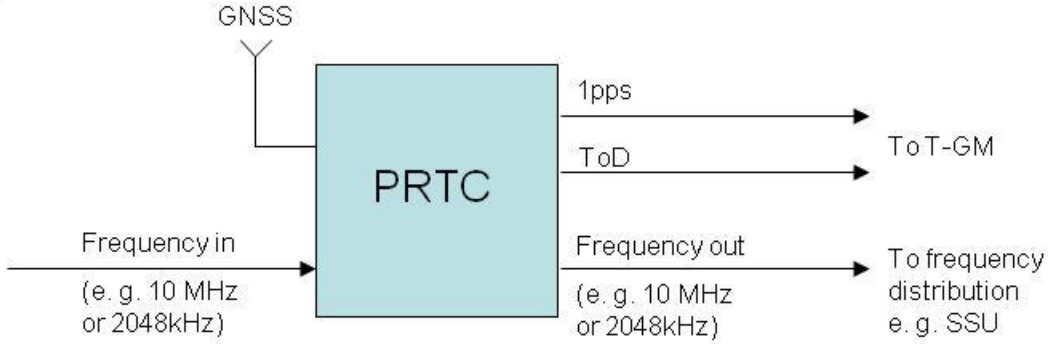


Figure 7/G.8275 – PRTC model with a physical layer frequency input

The ToD message is not defined in ITU recommendations. This is an anomaly given that the equipment on both sides of the interface, i.e., the PRTC and the T-GM, are defined by ITU.

NMEA 0183 is widely used but is not the only protocol available; other protocols are used around the World. One particular problem with NMEA 0183 is that leap-second data can only be accessed by using NMEA sentences which are proprietary to each GNSS manufacturer, making each PRTC/T-GM pair a partially-proprietary design. This goes against the grain of standards.

Also, the message protocol is only considered as passing time of day data. Other data, such as geographical position, is not considered; yet geographical location is a potential way to detect spoofing (*hint: base stations are not supposed to move*). Geographical location could also be useful in clock-selection. It is also needed if an application requires local time rather than UTC or GPS time.

Summary:

G.8265.1 is out-of-scope for phase-delivery.

G.8275.2 is under development for legacy networks and promises to be a useful way to easily back up a G.8275.1 "full-support" timing path. This also allows majority-voting to be used today to detect spoofing attacks.

G.8275.1 is fine providing SyncE retains its present purity and very good holdover is available at the end application. But G.8262 is not strong enough to ensure proper performance is maintained.

G.8262 was developed very quickly and allows large phase transients and high levels of noise to potentially spoil the performance of time-distribution if low-quality equipment is used; to preserve the current good performance, it is sensible to add a new clock type of G.8262.

None of the PTP profiles are protected against GNSS problems; access to alternative universal time-distribution mechanisms would be sensible in the future. This needs the interface into the T-GM to be fully defined (solving the problem that interfaces are currently partially-proprietary, and allowing geographical location data to be used to deliver local time to applications whilst potentially being useful in detecting spoofing attacks)

Useful links:

- http://www.npl.co.uk/upload/pdf/npltime-brochure.pdf
- http://www.astron.nl/radio-observatory/astronomers/users/technical-information/lofar-array-configuration/lofar-array-conf
- http://tf.nist.gov/time/twoway.htm
- http://www.cobham.com/media/883934/antennas_for_gps-gsm.pdf
- http://www.artechhouse.com/static/sample/Rao-150_CH02.pdf
- http://waas.stanford.edu/papers/Thesis/DavidDeLorenzoThesis07.pdf

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Thank you