Partial Timing Support - Performance Under Environmental Stress

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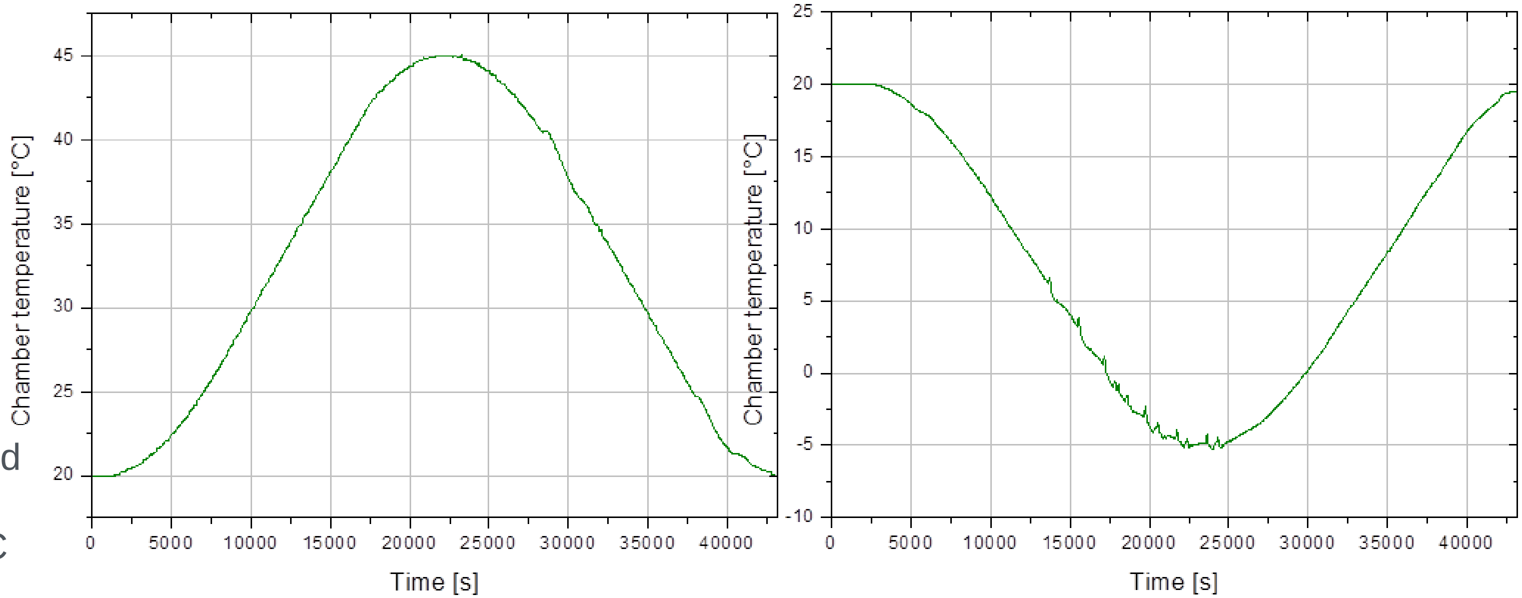
Time synchronization – measurements of BCs intended for partial timing support

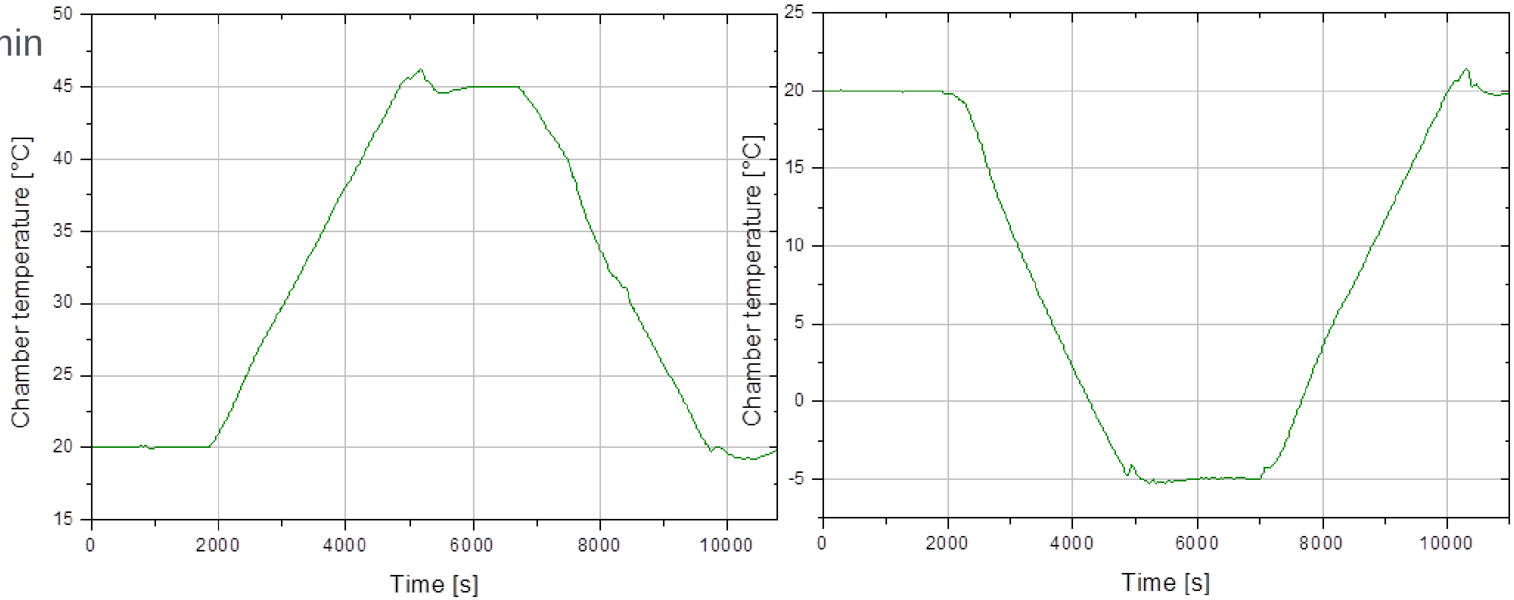
- Temperature profiles
- Delay files
- Measurement setups
- Results of 3 BC models

Temperature profiles

Sinusoidal 12h period
20 → 45 → 20 °C
and 20→ -5 → 20 °C
Duration 47000 s.



Linear slope 0.5 °C/min
20 → 45 → 20 °C
and 20→ -5 → 20 °C
Duration 11000 s.



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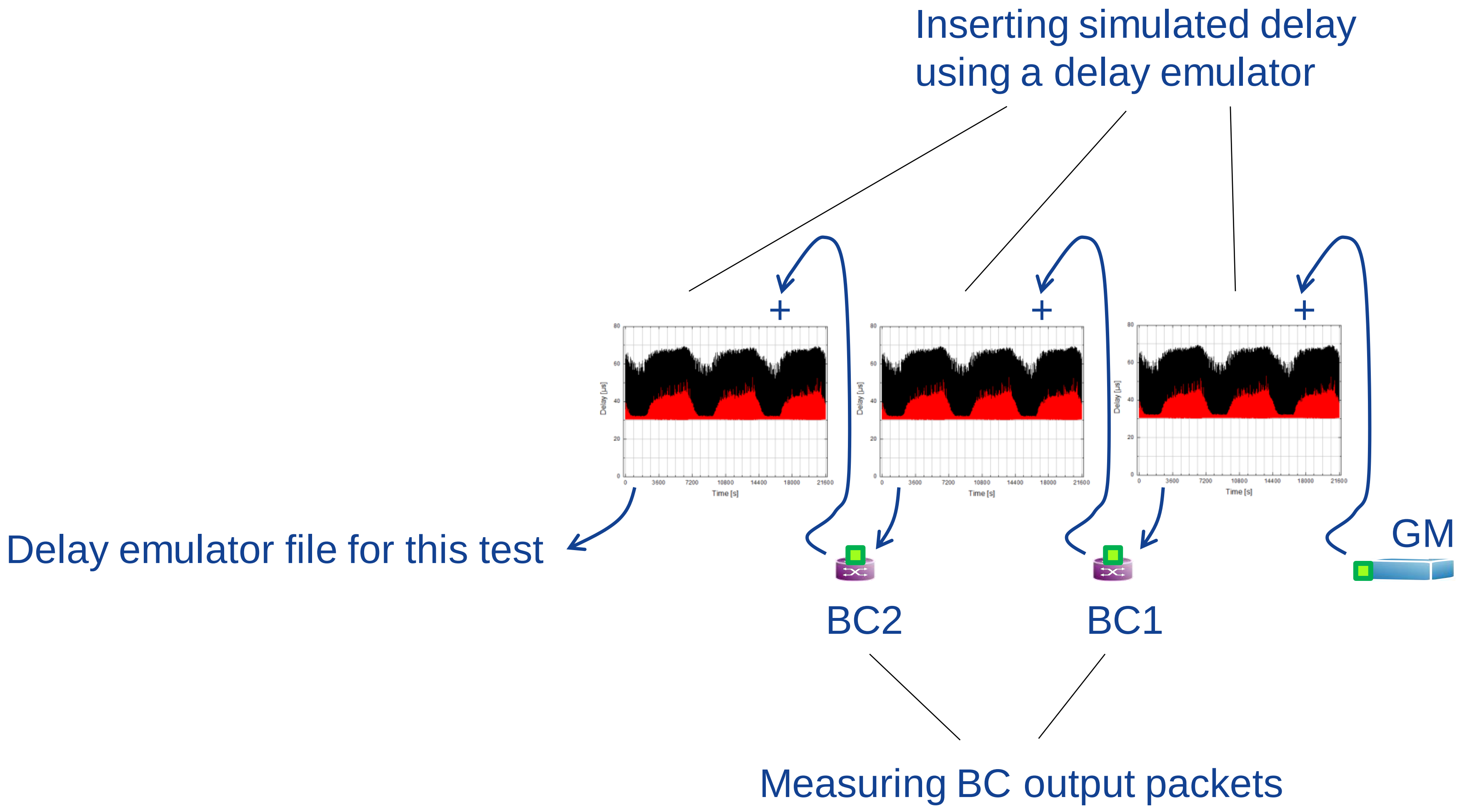
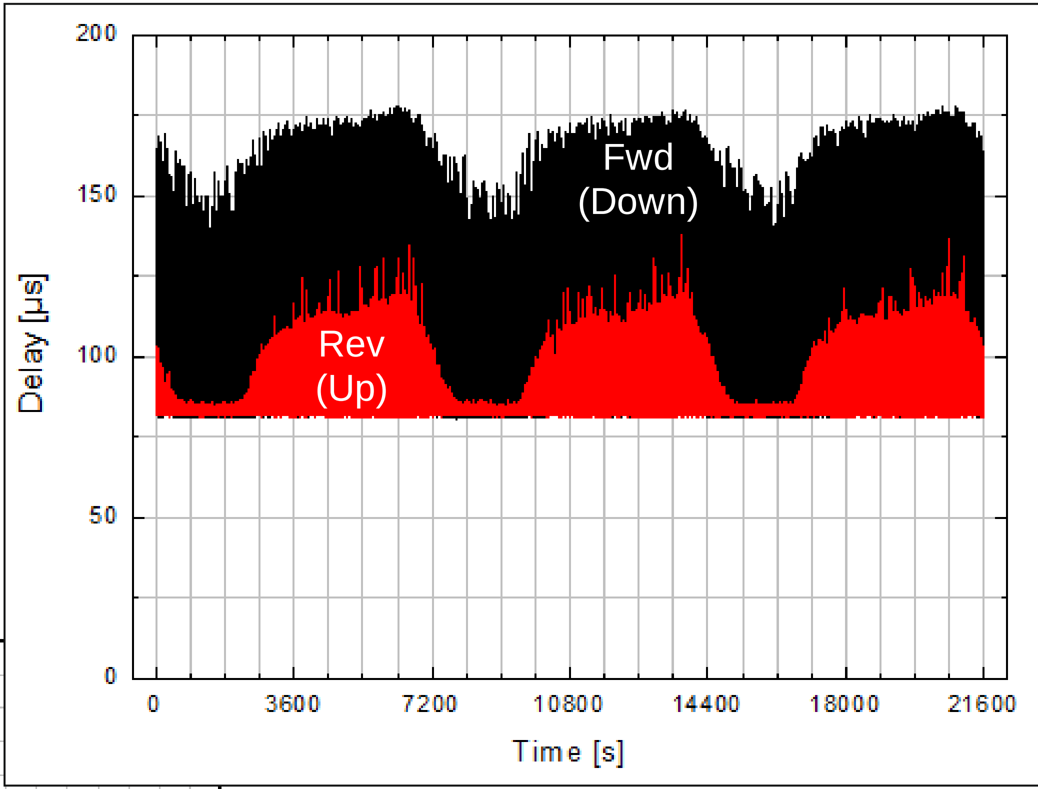
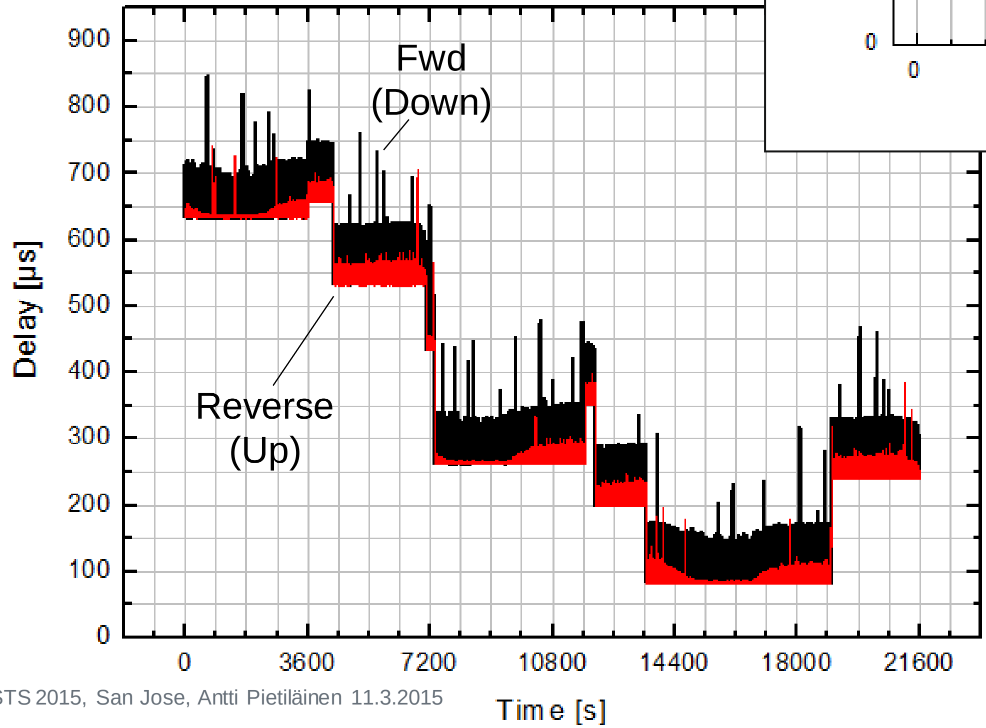
Building up the delay emulator file for the BC test



Final delay emulator files

- No bursts or delay jumps
- Asymmetric bursts and symmetric delay jumps





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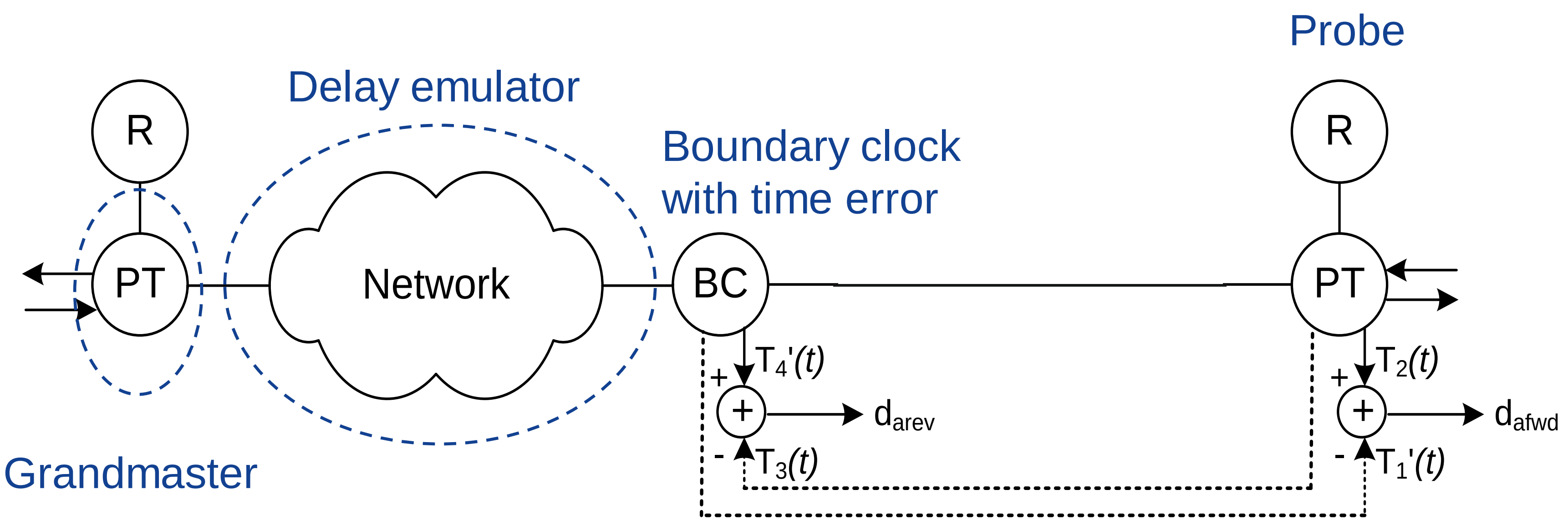
Measurement setup to measure the response of the BC

- The delay forward and reverse emulator files were loaded into an impairment emulator.
- The probe measured the apparent forward and reverse delays from the BC master port.



R	Time or frequency reference
PT	Packet timestamper

Measurement delay files, $d_{afwd}(i)$ and $d_{arev}(i)$, are used to determine BC time error

Figure processed from G.8260 rev. draft

BC time error determination

- In principle, the time error of the BC calculated from the apparent delays is

$$Time\ error = -d_{afwd}(i)$$
$$Time\ error = d_{arev}(i)$$

- However, neither fixed symmetric delay nor occasional “slower” packets cause error in a slave that uses the output of the BC as a source. Therefore the fastest 50% of packets were selected independently from forward and reverse directions and the time error was calculated as

$$Time\ error = [d_{arev}(j) - d_{afwd}(j)]\ /2$$

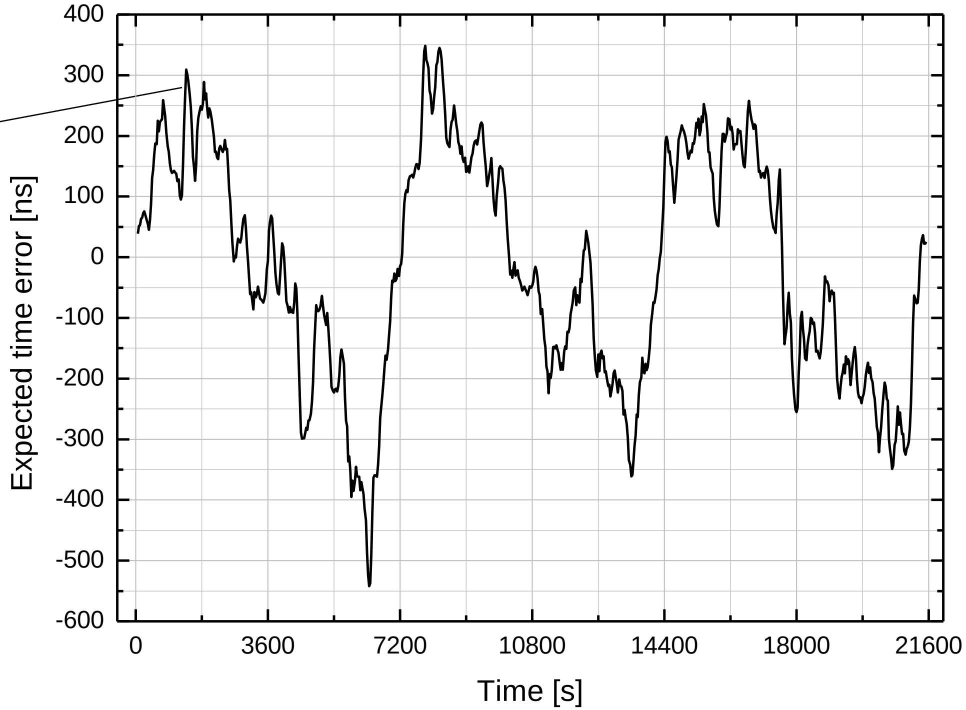
Delay files and determining the error

Expected error

- pktSelected two-way time error calculated from the delay emulator files (0.3% selection from 30 s windows)

Measured error

- pktSelected two-way time error from apparent delays measured by the probe (50% selection from 30 s windows)

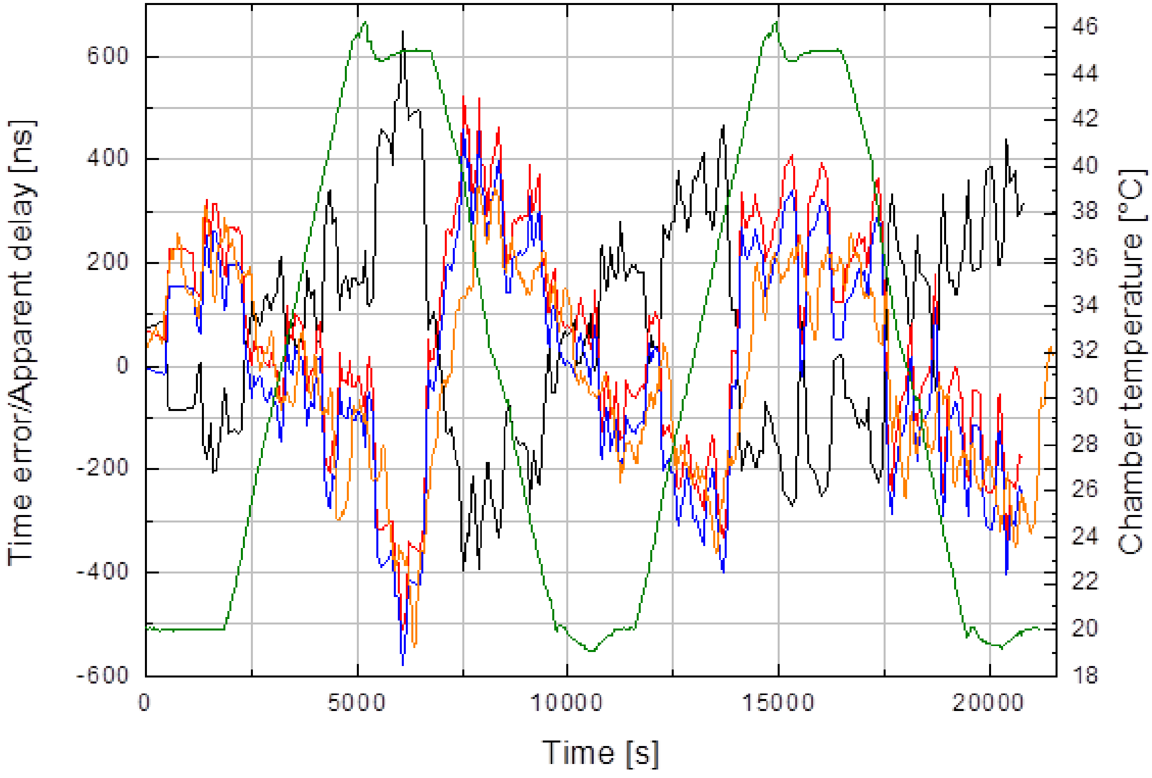


BC1

Delay files without bursts

- The fixed asymmetry error of the BC was only about -8 ns.
- The BC operates in the varying temperature almost as if there was no temperature changes.

Green: Temperature, Black: fwd apparent delay
Red: rev apparent delay, Blue: time error
Orange: expected time error



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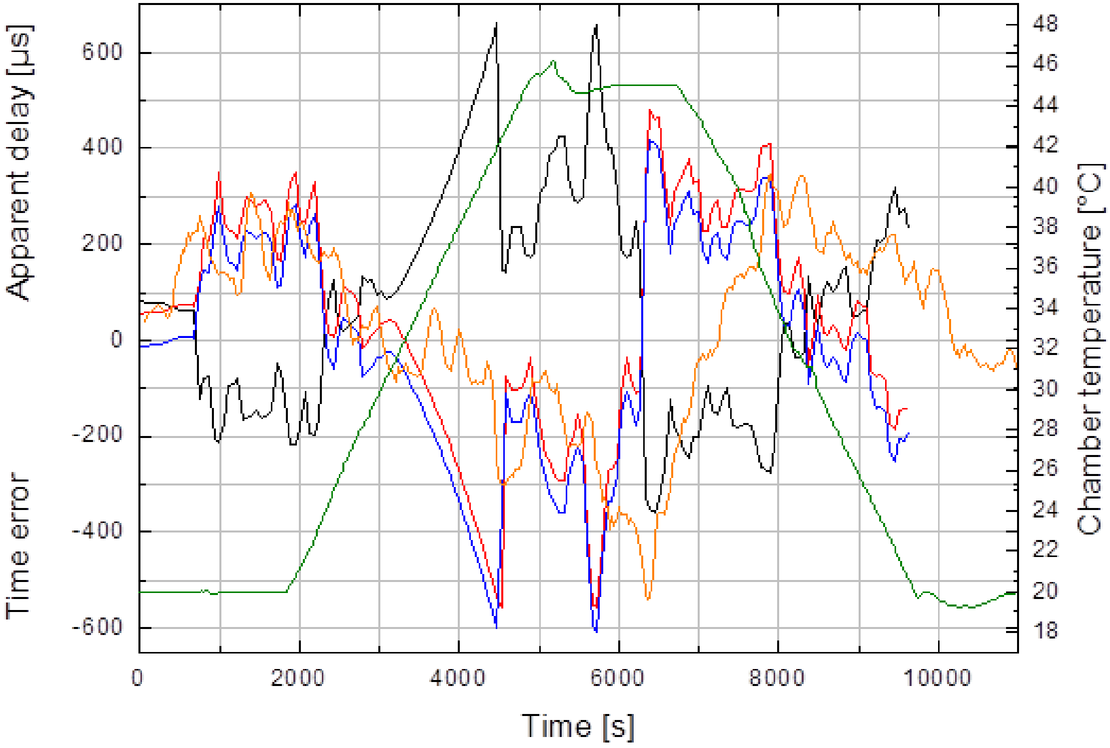
BC1
Delay files with bursts

- Some of the bursts or delay jumps cause additional time error.
- The problems are fixed quick enough so that the maximum error is only slightly larger than in the case of no bursts.

Green: Temperature, Black: fwd apparent delay
Red: rev apparent delay, Blue: time error
Orange: expected time error



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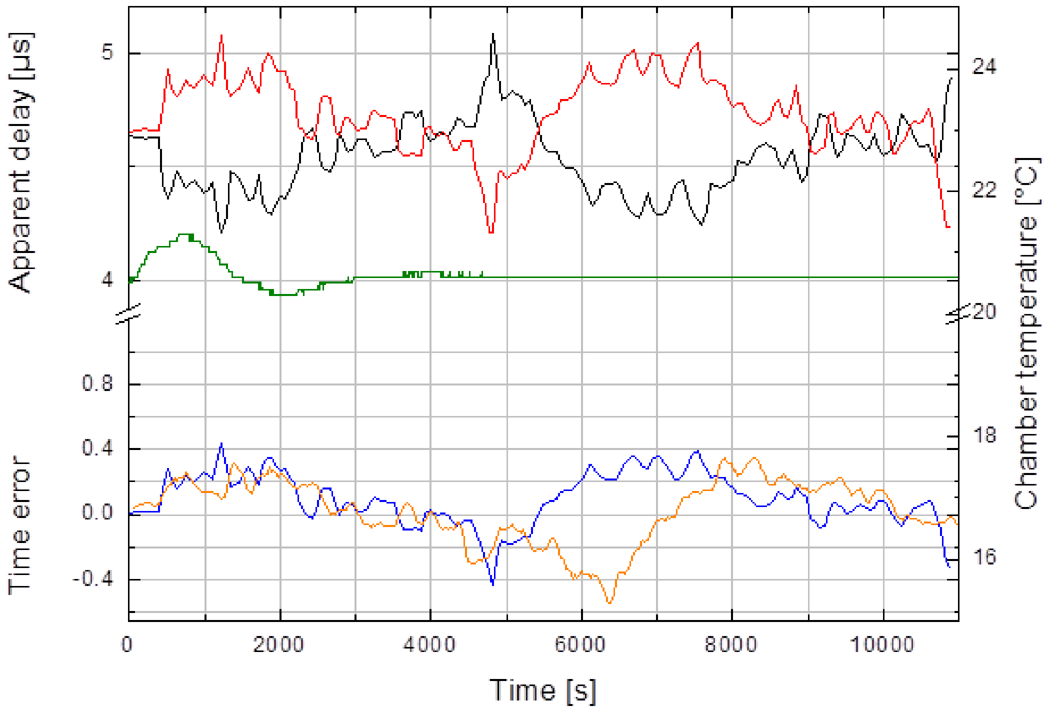
BC2

Delay files without bursts
Constant temperature

Green: Temperature, Black: fwd apparent delay
Red: rev apparent delay, Blue: time error
Orange: expected time error



- The time stamps have 4.65-µs symmetric time error that cancels out.
- The inherent time error (no delay file) varied between 0 and -50 ns.
- Result with delay file is good in constant temperature although the behavior does not correlate with the expected behavior very well.

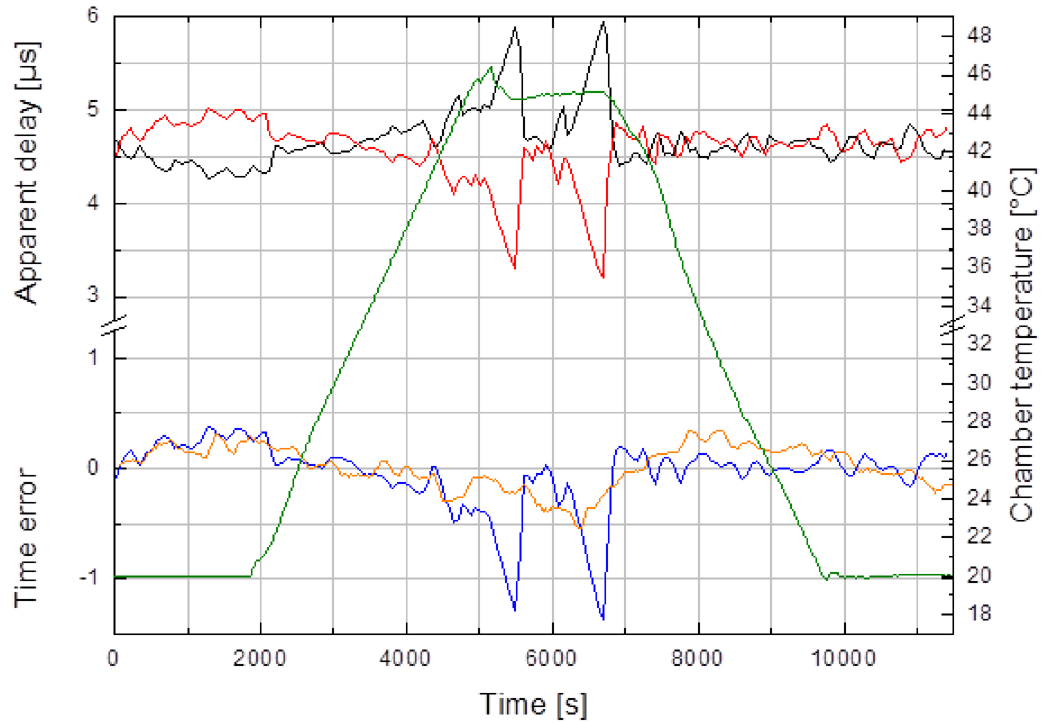
Antti Pietiläinen 20.11.2014

BC2

Delay files without bursts
Varying temperature

- The combination of the two impairments, delays and temperature variation, causes excessive time error.

Green: Temperature, Black: fwd apparent delay
Red: rev apparent delay, Blue: time error
Orange: expected time error

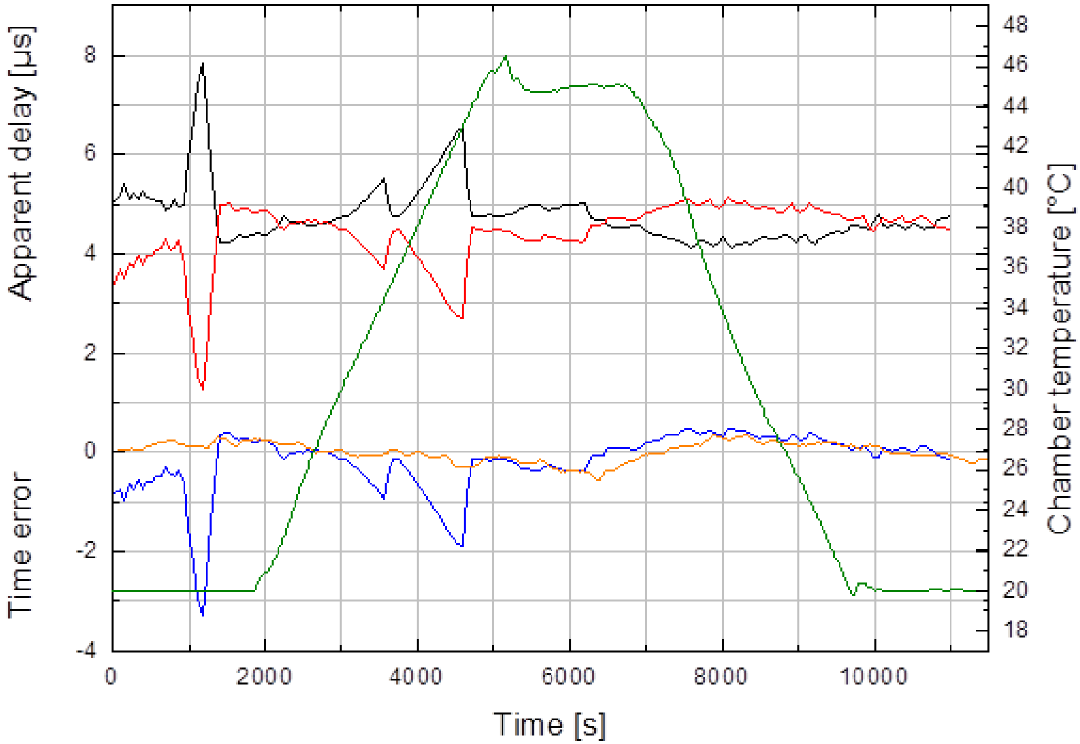


BC2

Delay files with bursts
Varying temperature

- The combination of the three impairments, delays, bursts, and temperature variation, causes unacceptable time error.

Green: Temperature, Black: fwd apparent delay
Red: rev apparent delay, Blue: time error
Orange: expected time error

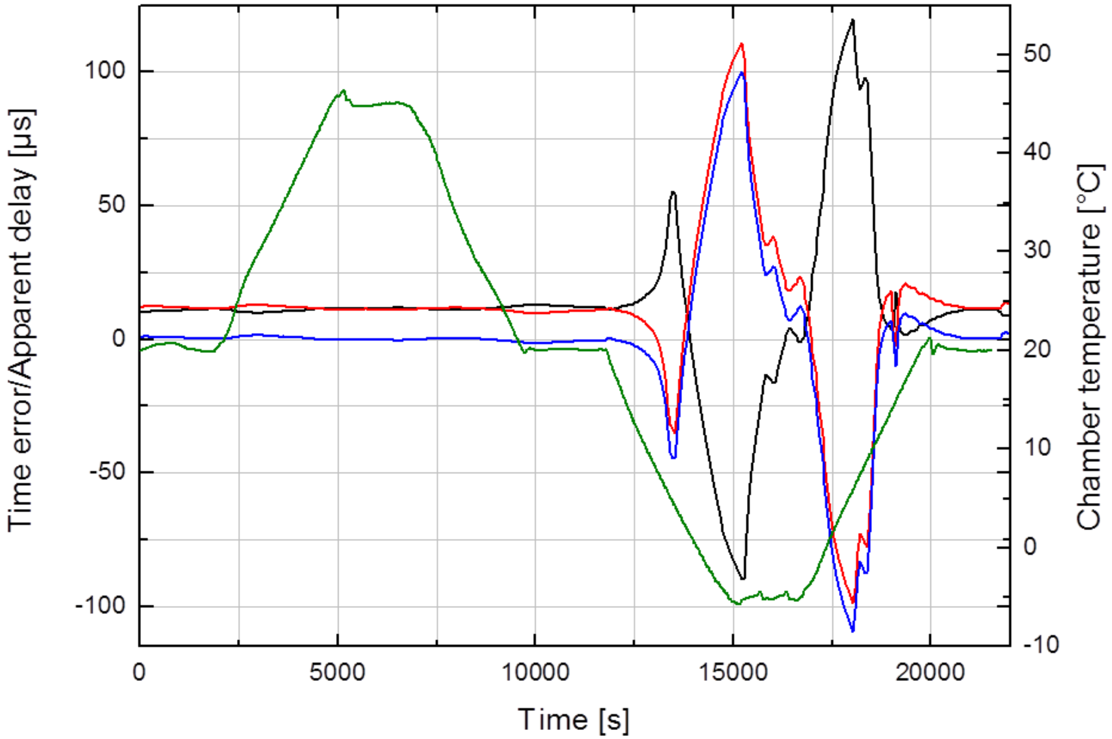


BC3

Delay files with bursts
Varying temperature

- TCXO (temperature compensated crystal oscillator), based low-cost unit which affects the performance in varying temperature.
- Especially the cold extreme caused problems at the time of the measurements.

Green: Temperature, Black: fwd apparent delay
Red: rev apparent delay, Blue: time error



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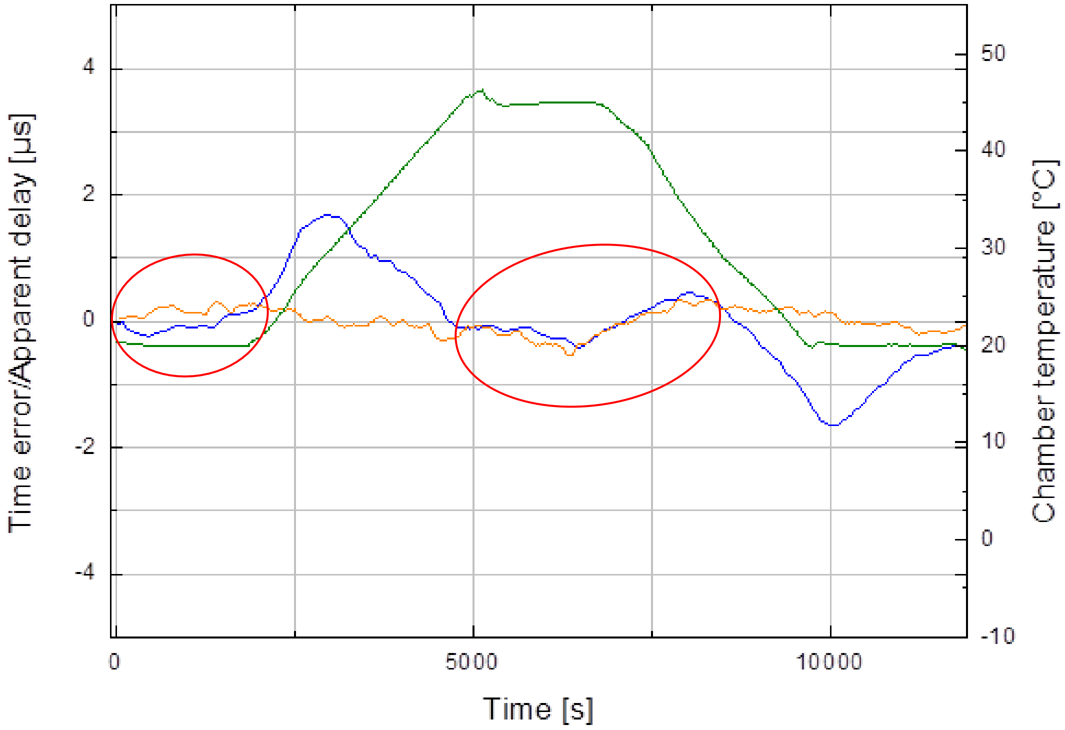
BC3

Delay files with bursts
Varying temperature

- The first half of the graph in the previous slide is shown here.
- The temperature variation causes already in this part problems that need attention. However, during steady temperature the performance is quite good.
- Unfortunately the device was not measured without temperature variation so that the performance without temperature variation has not been determined.

Green: Temperature
Blue: time error
Orange: expected time error



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Summary of boundary clocks for time synchronization

- BC1 is almost mature and ready for deployments
- BC2 has to fix some problems. With the standard delay file the results are good although there is some evidence of non-linear response. When adding either temperature variation or bursts/delay jumps or both, the algorithm seems to occasionally lose faith to the timing packets and consequently drift out of specification
  - Some “intelligence” should be stripped and the algorithm should follow the timing packets more strictly.
- BC3 has a too slow tuning algorithm considering the limited temperature stability of the oscillator. Like BC2, BC3 seems to have also some unnecessary “cleverness”, which leads to highly non-linear response to packets.

- The situation is promising – but some simple improvements are needed:
  - Packet selection windows should be long enough to accept short bursts without effect to the output
  - The algorithms should be made immune to symmetric delay jumps – and need not be prepared for asymmetric delay jumps.
  - The algorithms should not utilize longer averaging times than the oscillator stability allows.
  - Special “cleverness” features often lead to unnecessary hold-over –type situations where the clock drifts out of specification. Nonlinear cleverness should be stripped.