Time Synchronization in a Campus Network

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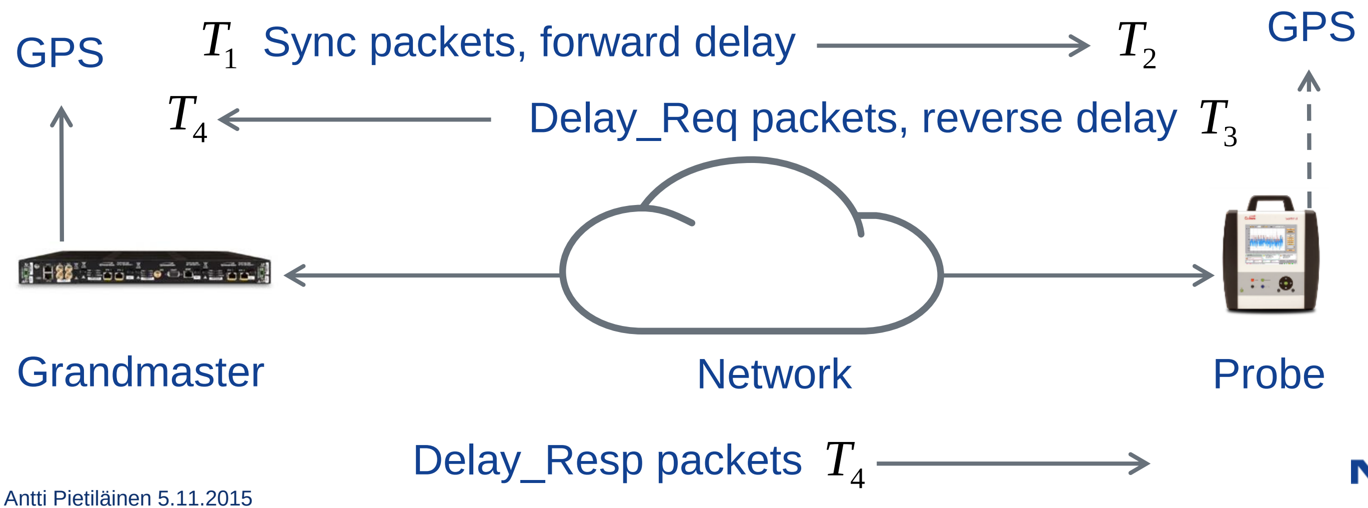
- Measurement scheme
- Network
- Measurements
- Conclusions

Introduction

- G.8275.2 partial timing support scheme is an attractive way to carry time synchronization without or with partial on-path support.
- Especially suitable would be relatively modern, less than ~4 years old constrained networks.
- Office campus networks are typical representatives of constrained networks.
- In these environments also high-speed cellular data at high volumes are desired – leading to the need of small cells that may require time synchronization.

Packet delay measurement principle for estimating the time error caused by a network

- The grandmaster is synchronized via GPS continuously.
- The probe is synchronized first via GPS. Then it is taken to the measurement location with battery backed rubidium oscillator used for holdover.
- Before and after the measurement the time base of the master and probe are compared. A linear drift estimation based on these measurements is used to remove drift during the probe holdover.



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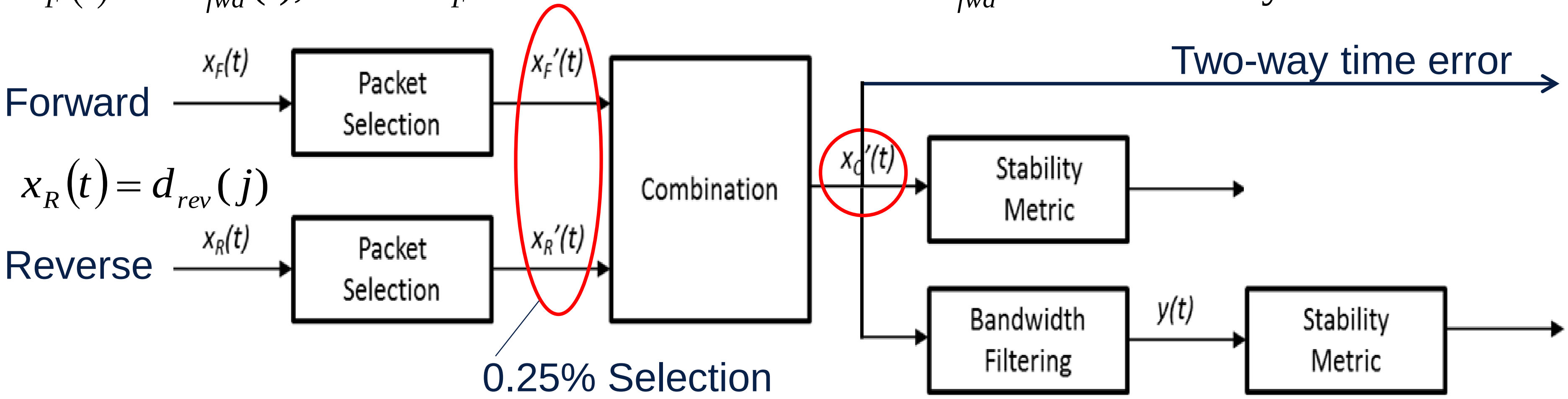
Estimating time error of a packet clock based on delay measurements

Calculating two-way time error based on percentile selections of forward and reverse delays as defined in G.8260 (08/2015).

$$x_F(t) = -d_{fwd}(i), \text{ where } x_F \text{ is forward time error and } d_{fwd} \text{ is forward delay}$$



Two-way offset, or two-way time error is calculated using packet selected time error sequences:

$$x_C'(n\tau_s) = \frac{x_R'(n\tau_s) + x_F'(n\tau_s)}{2}$$

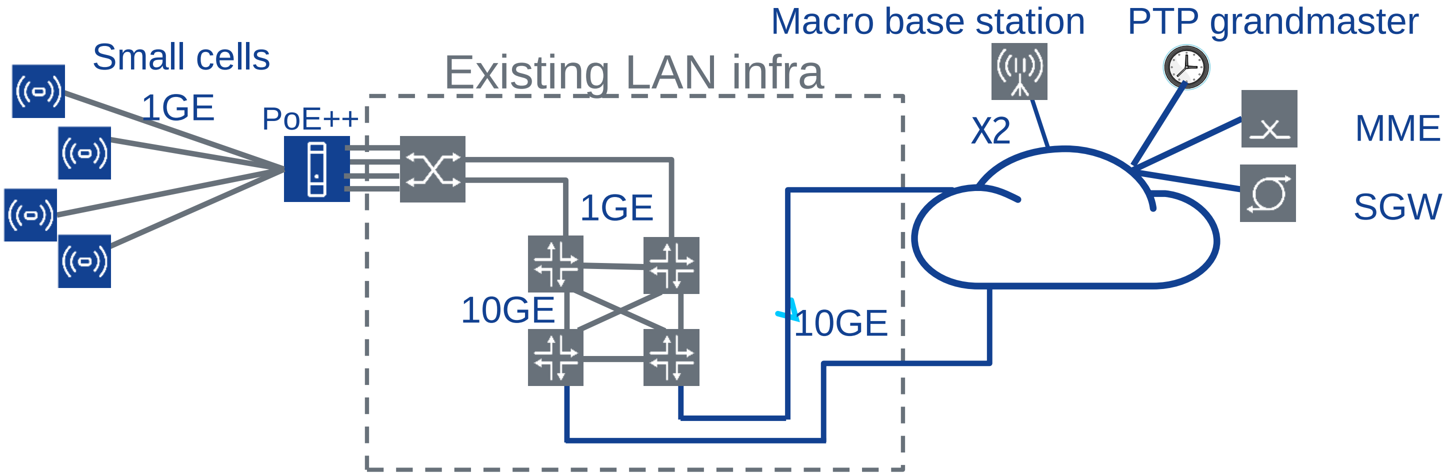
Selection window size, τ_s is 200 s.

Selection percentile is 0.25%.

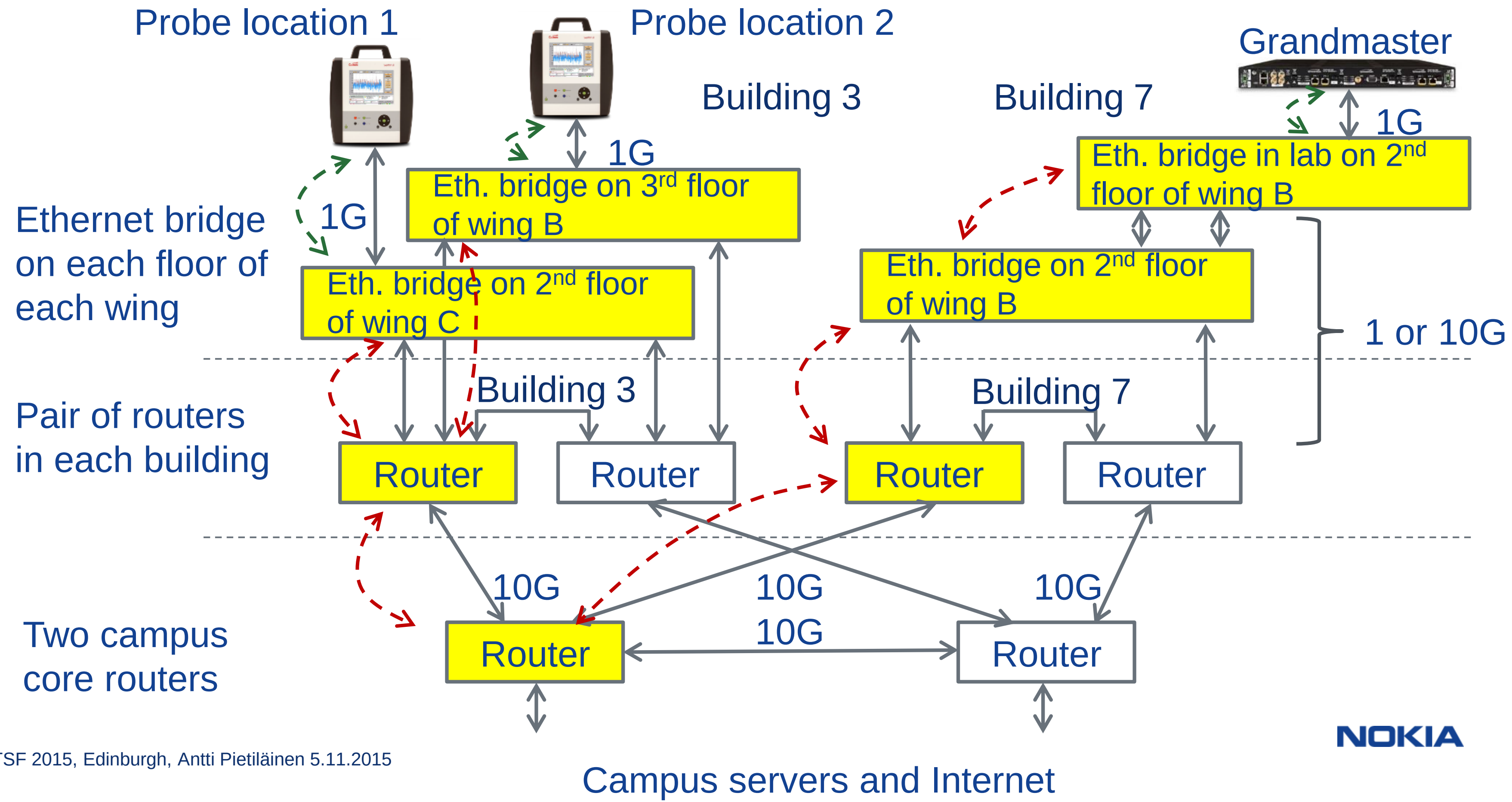
Small cell indoor deployment at Nokia campus using Enterprise LAN

Utilized also for precision packet delay measurements

- A small cell indoor installation is being carried out with minimal investment on backhaul by reusing the Enterprise LAN infrastructure.
- The network is frequency synchronized using a remote PTP grandmaster. Some locations are used to test time synchronization over the standard LAN by using another grandmaster at the campus.



Test setup for time synchronization, case 1 and 2



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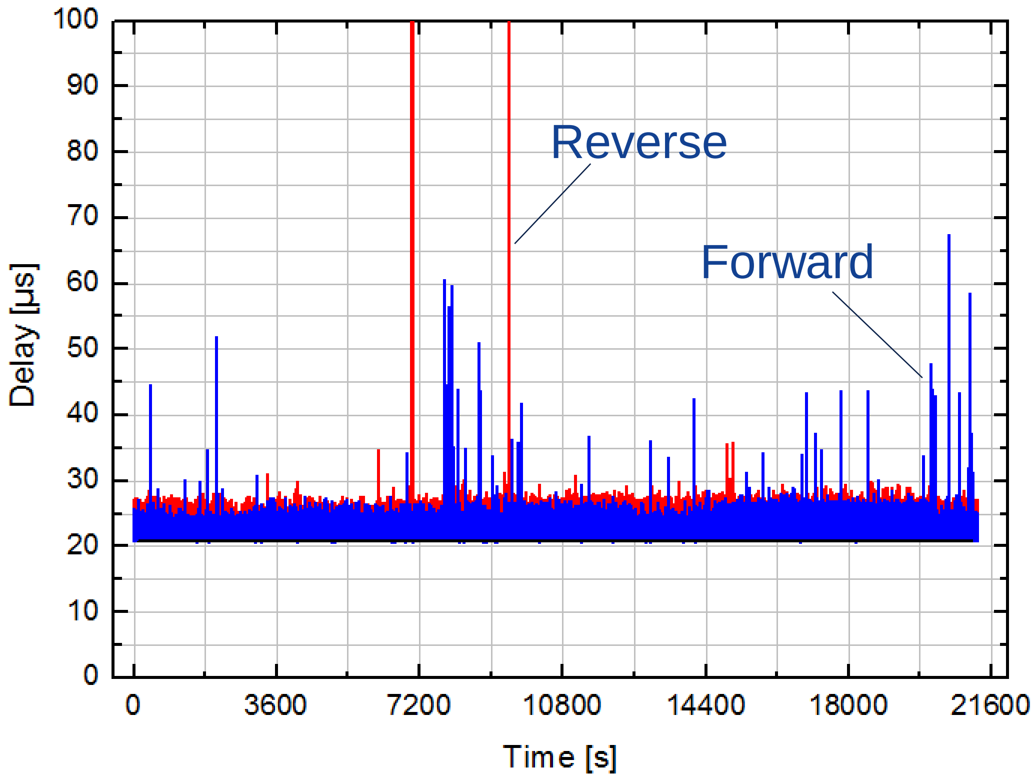
Case 1: Delays between the grandmaster and the probe at location 1

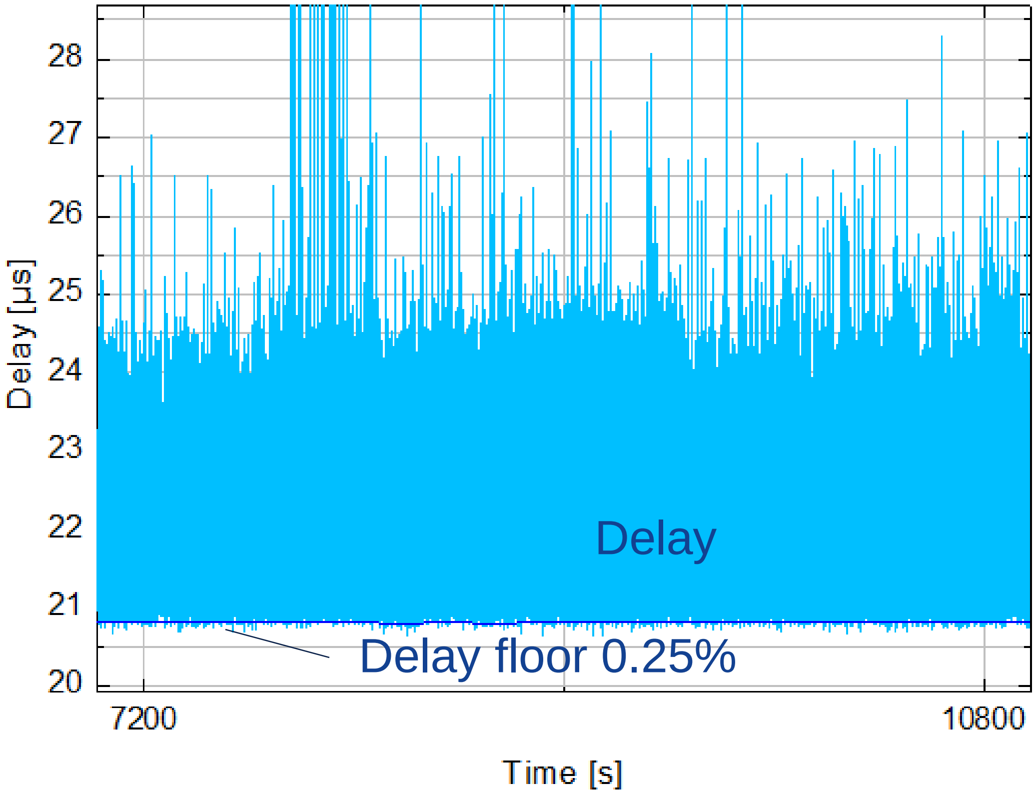
Three switches and three routers on the way

- The delay variation is very small apart from a few stray packets.



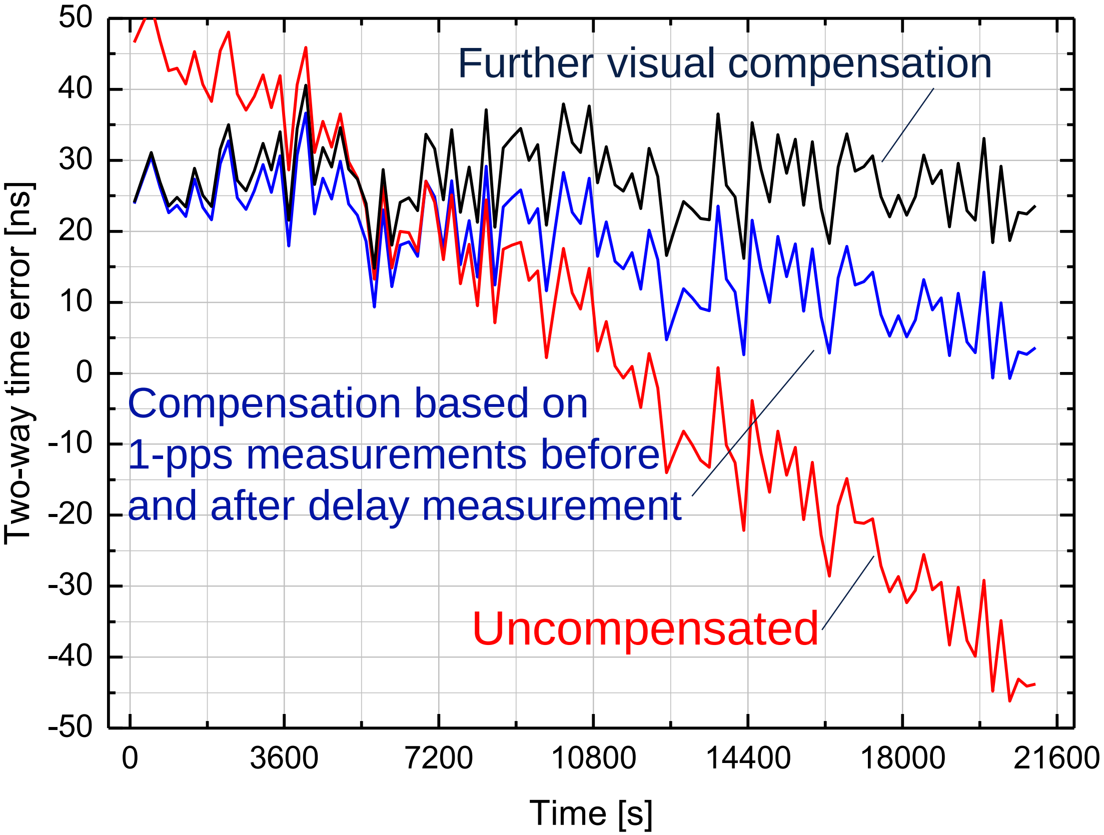
Case 1, delay and delay floor

- The delay floor at 20.8 µs is quite smooth.



Case 1: Time error determination, removal of oscillator drift

- The time error is so small that the oscillator drift of the probe becomes dominant.
- After removing the offset (+23 ns) and drift (-71 ns) between the master and the probe, there still seems to be a drift.
- Since the remaining drift forms almost a linear slope (-20 ns), and exists in FWD and REV directions it was removed too.



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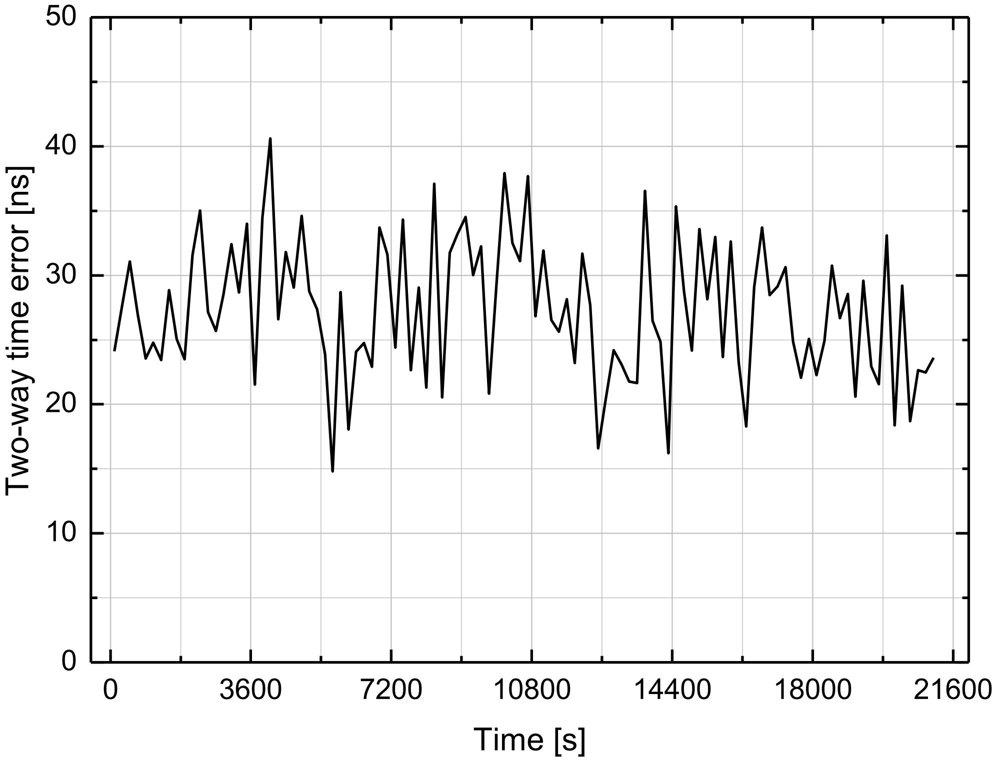
Case 1: Time error after compensation

- The peak time error is 41 ns.
- The uncertainty in the time error is as large as the minuscule measurement result.
- The p-p dynamic time error is 26 ns.



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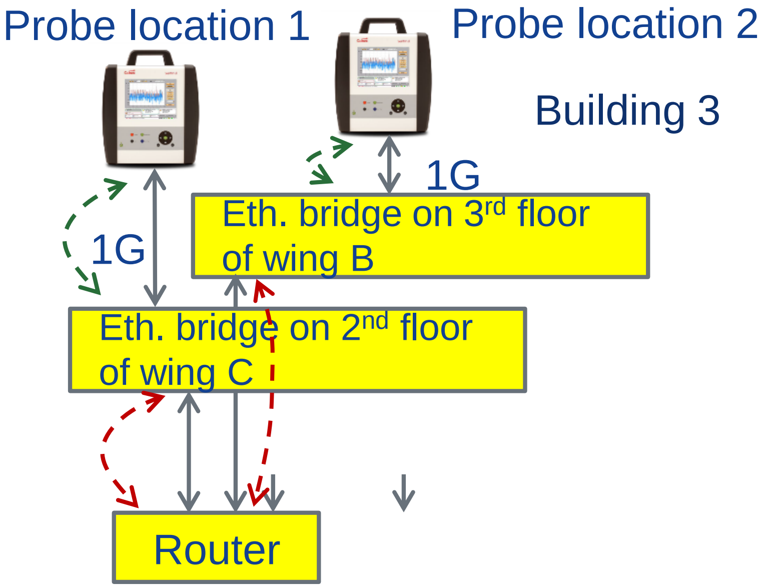
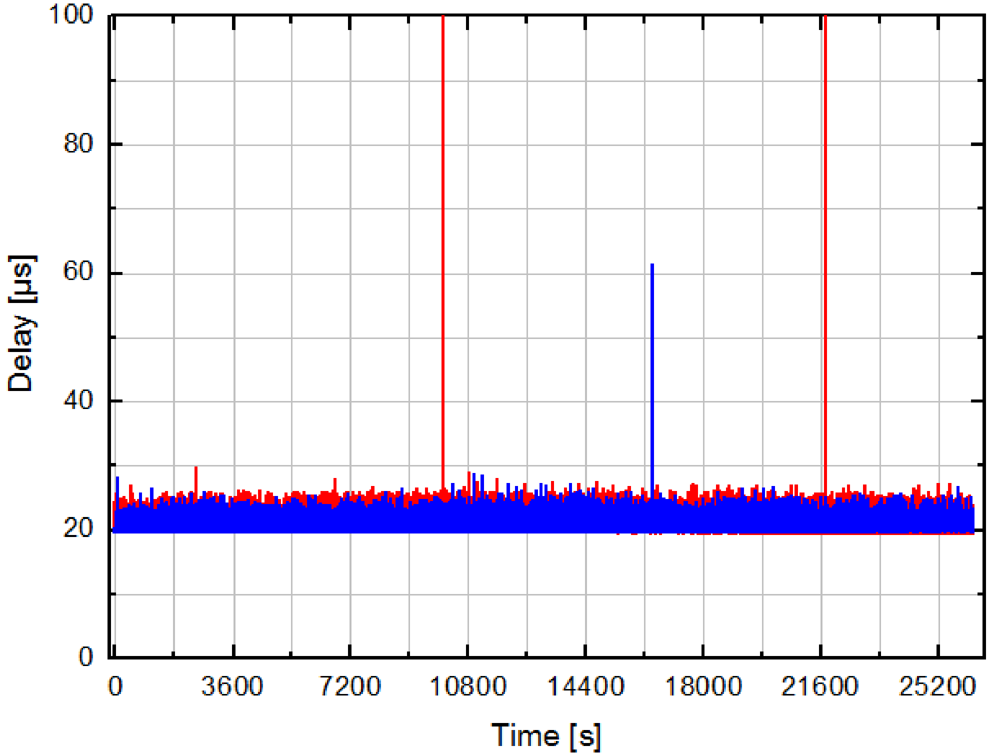
Case 2: Delays between the grandmaster and the probe at location 2

Similar route except for the last router port and Ethernet bridge

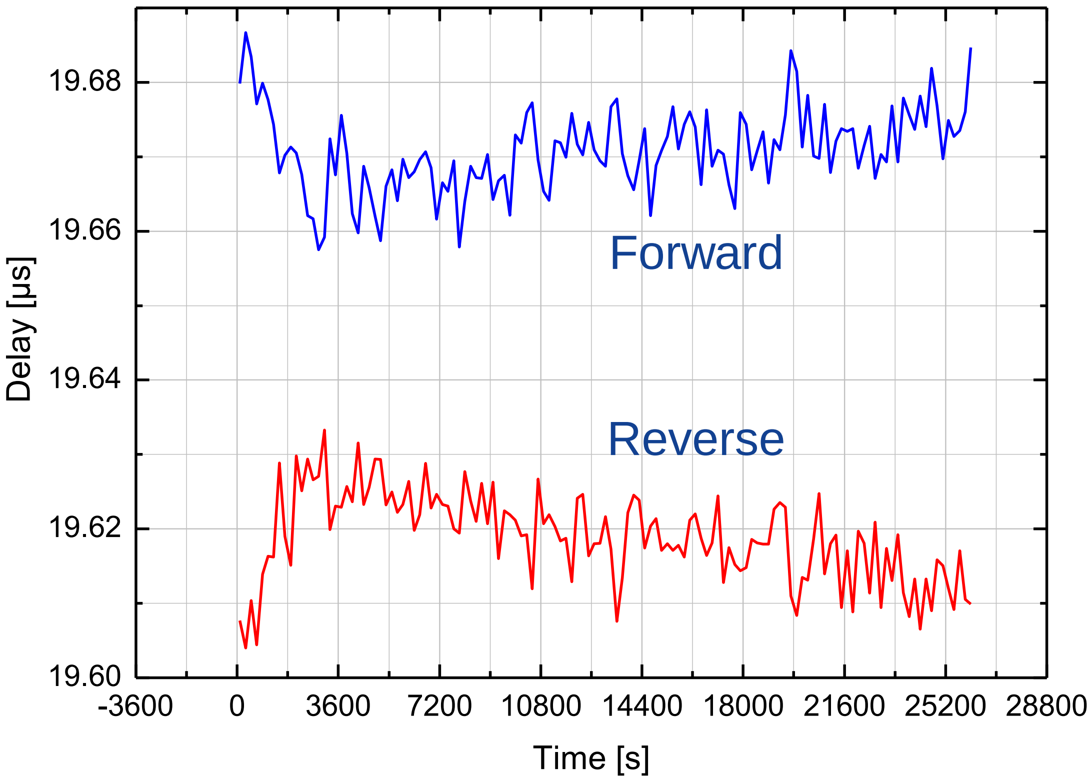
- Again the delay variation is small.





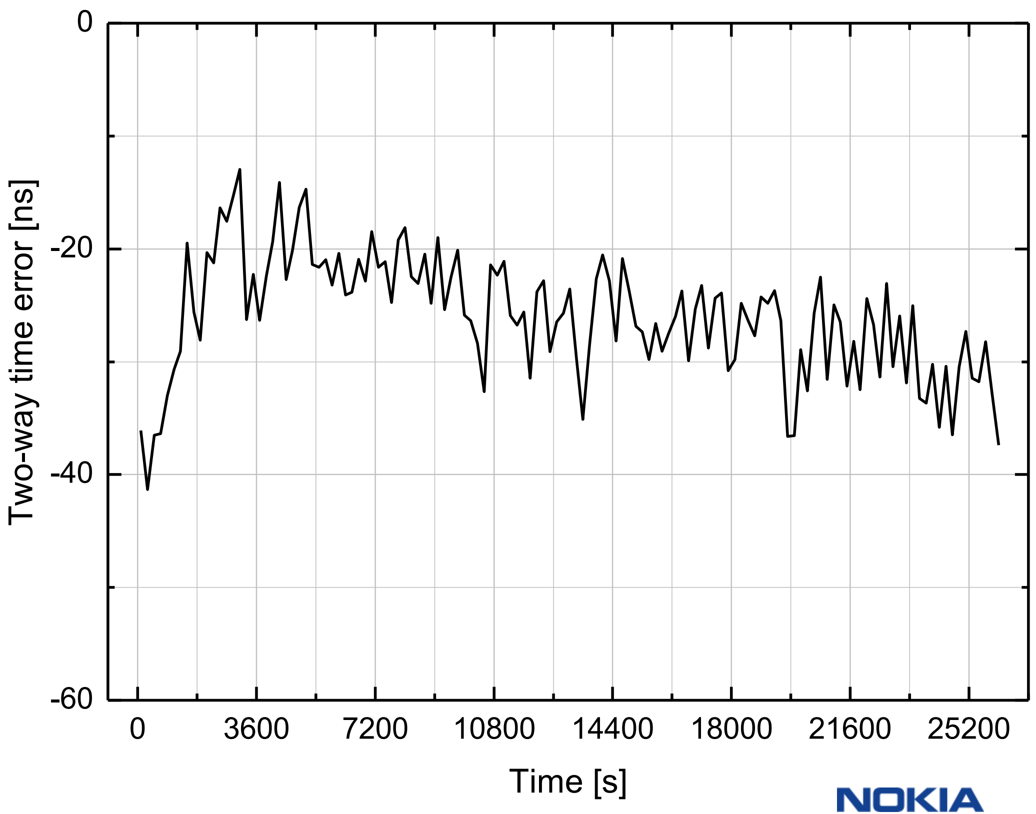
Case 2: Delay floors of forward and reverse direction

- The delays are now about 19.6 ns after compensating the probe offset (42 ns) and drift (196 ns) using the 1-pps signal comparison.
- Thus the delays are 1.2 µs smaller than in Case 1.
- Since the major patterns are mirror images, the patterns are due to phase drifts in the probe and in the master, probably of equal magnitude.



Case 2: Time error after drift compensation

- The time error is about the same as in the previous measurement but with different sign, i.e. there is a 60 ns time difference.
- The steep slope in the beginning and the gentle slope until the end are due to phase drifts of the time references at each end.



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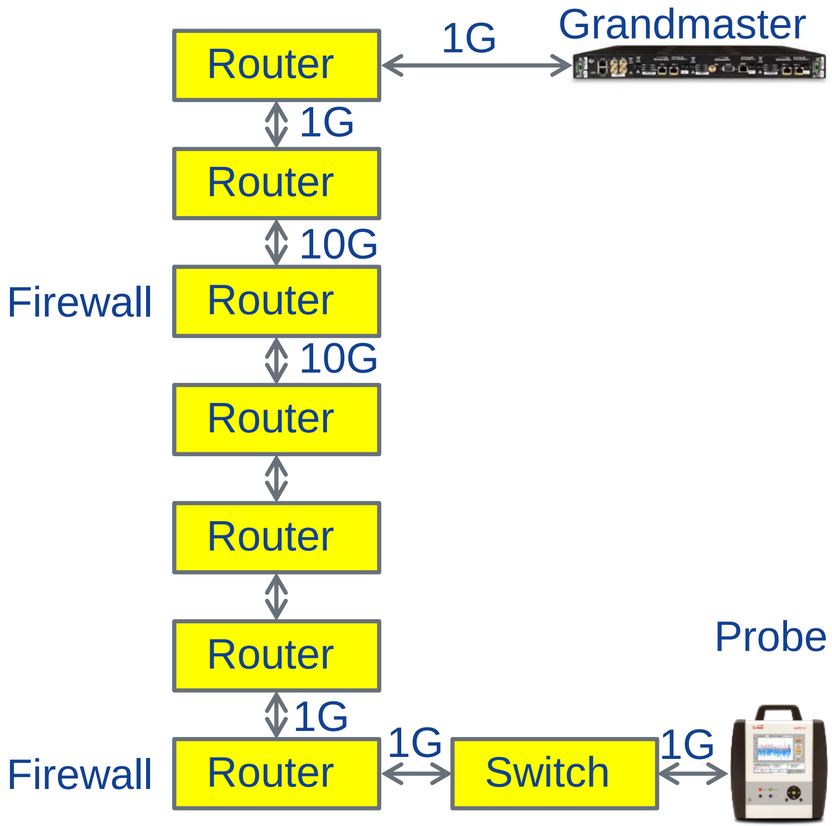
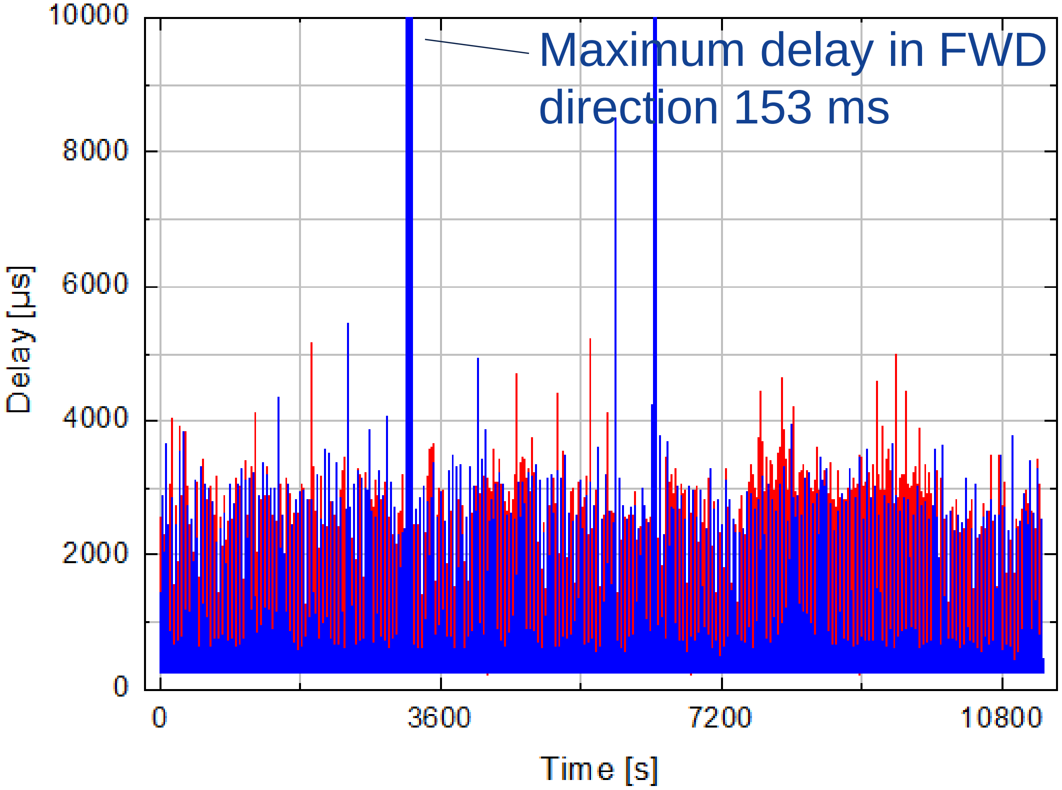
Case 3: A large network supporting R&D

- A chain of one switch and seven routers incl. 2 firewalls.



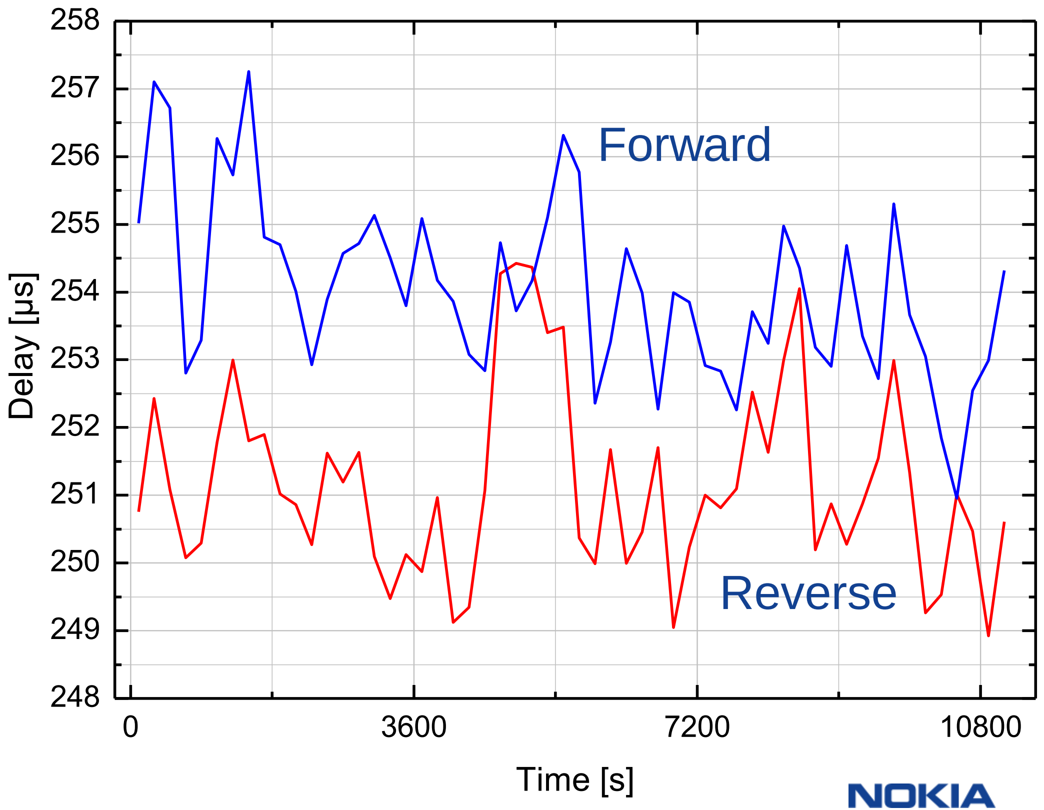
Case 3: Delays between the grandmaster and the probe through the long chain

- Vastly larger delays compared to the previous network, maybe due to the firewall.



Case 3: Delays between the grandmaster and the probe through the long chain

- Floor delays are 13 times as large as in the previous cases



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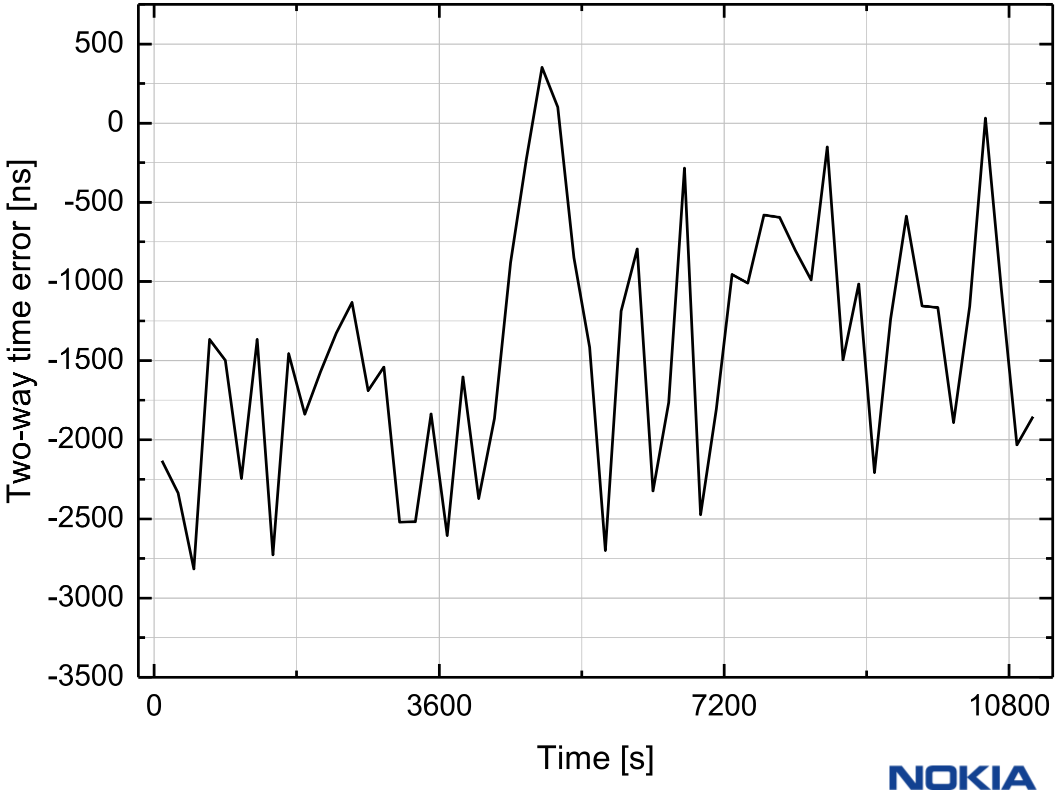
Case 3: Time error

- The time error is about twice more than acceptable and almost hundred times larger than in Case 1 and 2.
- The p-p dynamic time error is larger than the largest absolute time error.



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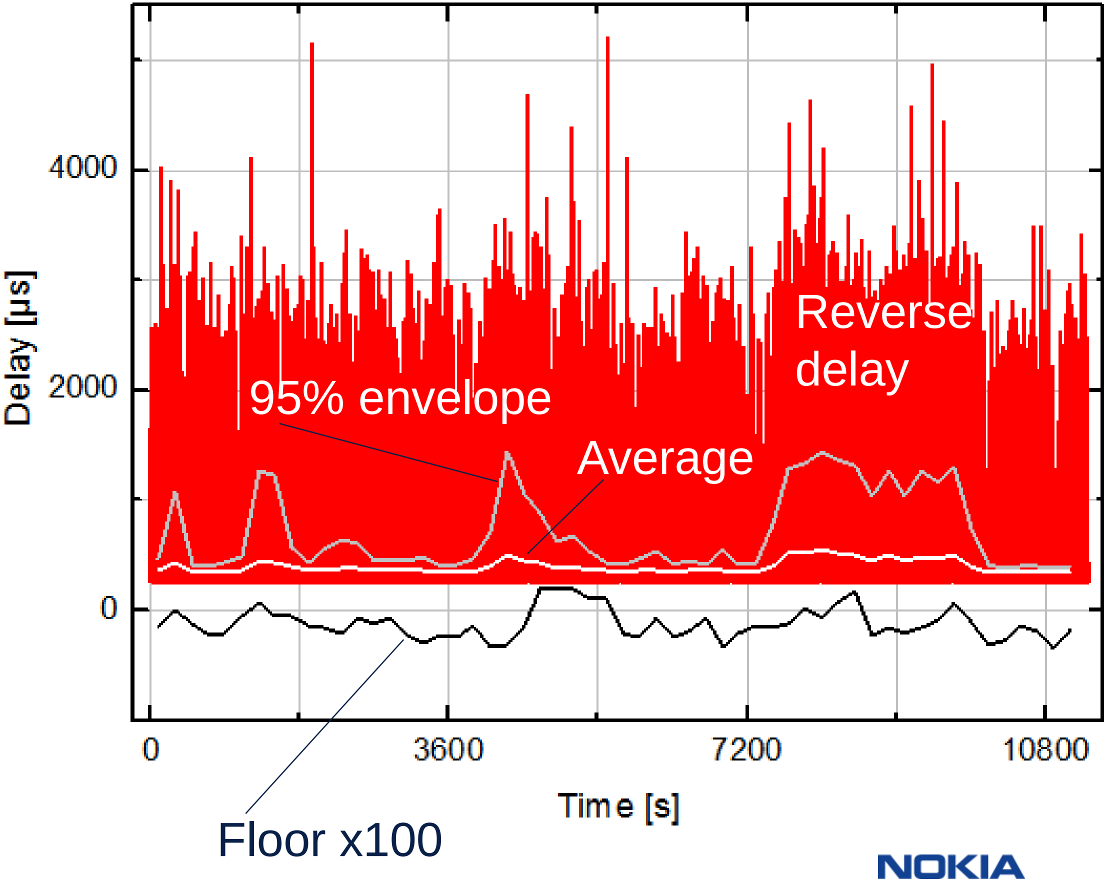
Case 3: Correlation between the delay floor and the delay in general

- Unlike in the lab, the correlation between the delay floor and the delays of the majority of packets is weak.
- The largest delay floor peak at around 5000 s does not correlate at all with the average delay or 95% envelope.



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Conclusions

- Both fixed and dynamic time errors in Case 1 and Case 2 are extraordinarily small and are consequently very promising initial results.
- The minimal errors are certainly due to good luck. A proof of this is the difference, 60 ns, between Case 1 and 2 even though the route differs only by one router port and one bridge.
- Case 3 depicts a complicated network that is clearly too demanding for time synchronization using partial timing support. Thus, the wide range of possible use cases has limits that need to be determined.
- There is still more research to be done but it is certain that G.8275.2 partial timing support scheme is becoming reality.