

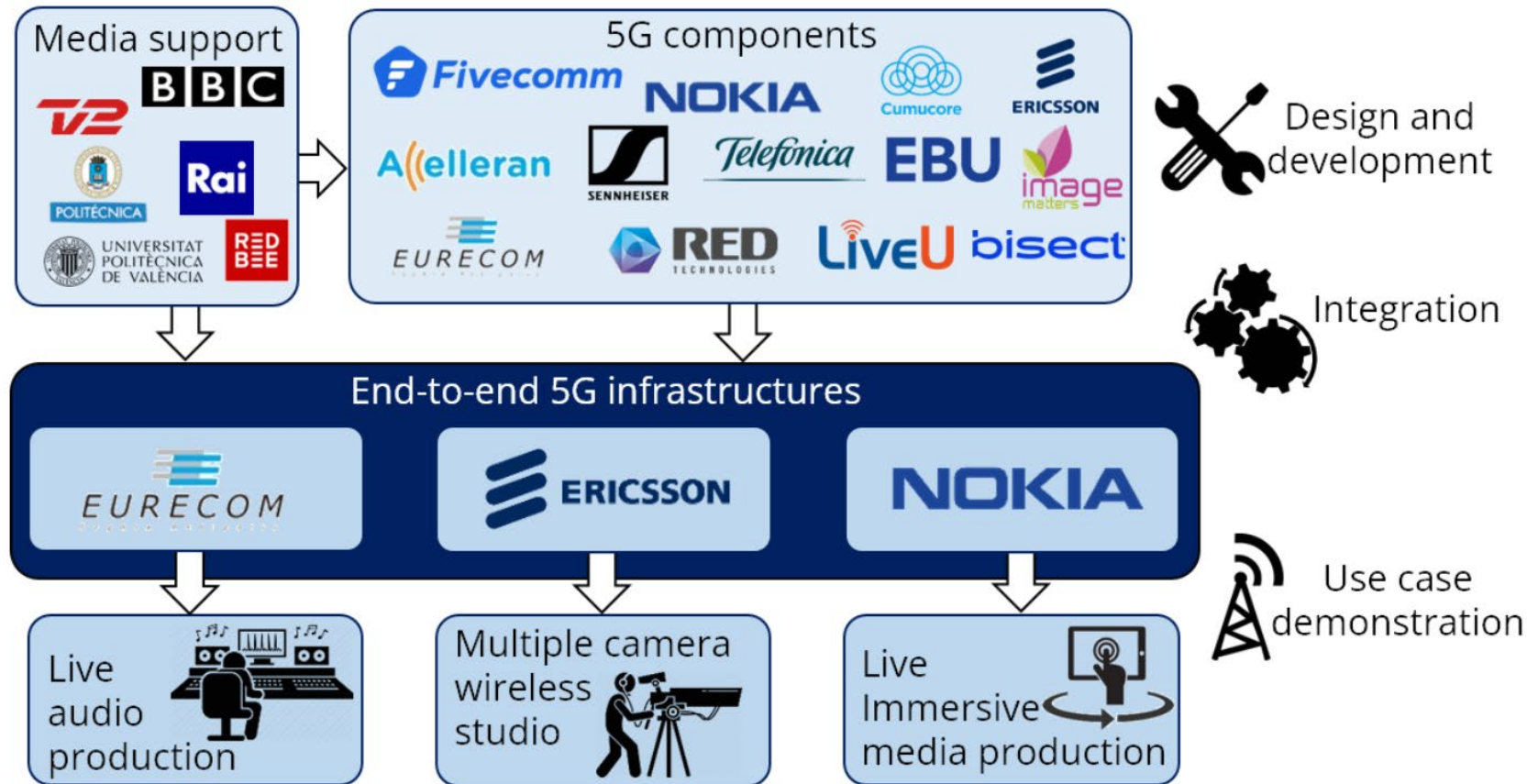
Practicalities and analysis of using PTP over 5G systems with dedicated time synchronization support for media production

Presenting: Ievgen Kostiukevych (EBU), Pavlo Kondratenko (EBU)

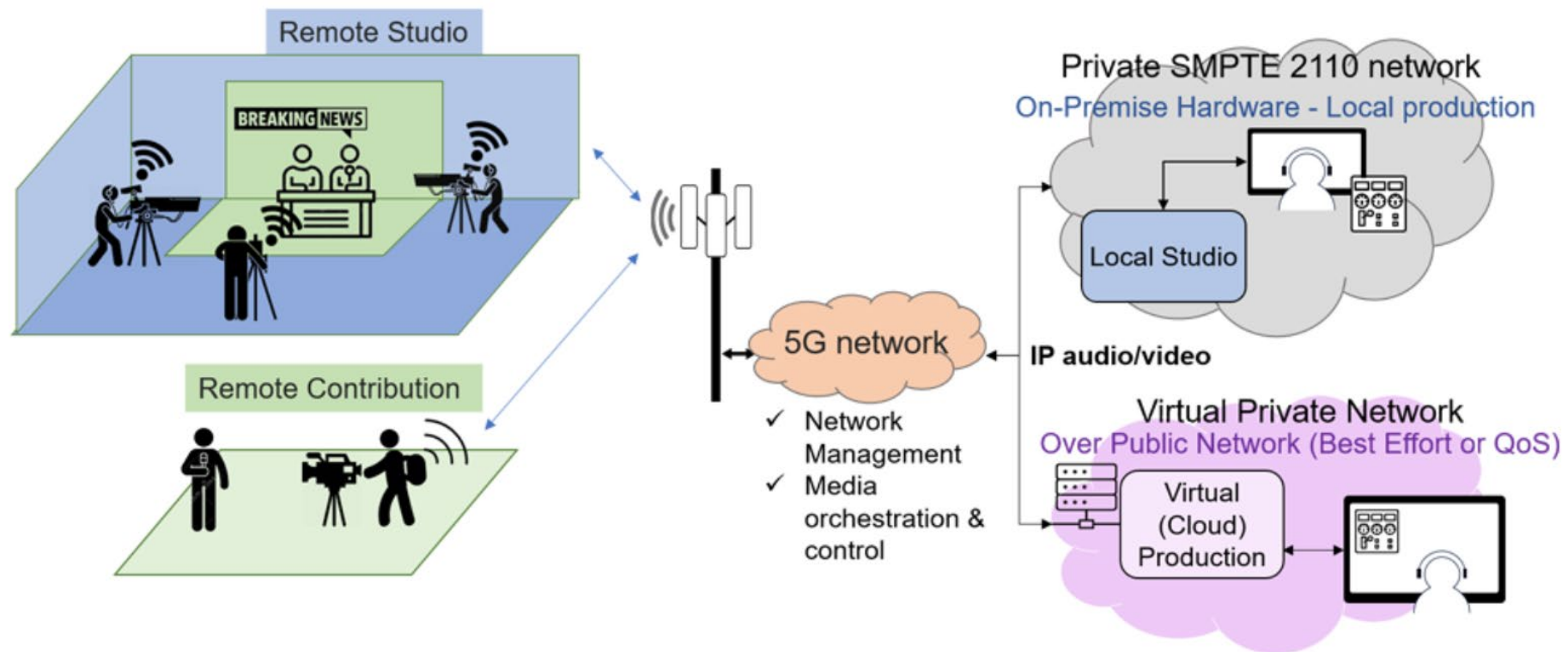
Co-Authors: Thorsten Lohmar (Ericsson), Mohamed Nabil Ibrahim (Ericsson), Thomas Kernen (NVIDIA)



About 5G RECORDS



About UC2



Problem Statement



- How do we synchronize multiple wireless cameras?
- PTP vs NTP vs SIB9
- PTP is already used for ST 2110 on the wired side
- Will PTP work over 5G at all?
- What accuracy is good enough?
- Unicast/Multicast

PTP without correction field

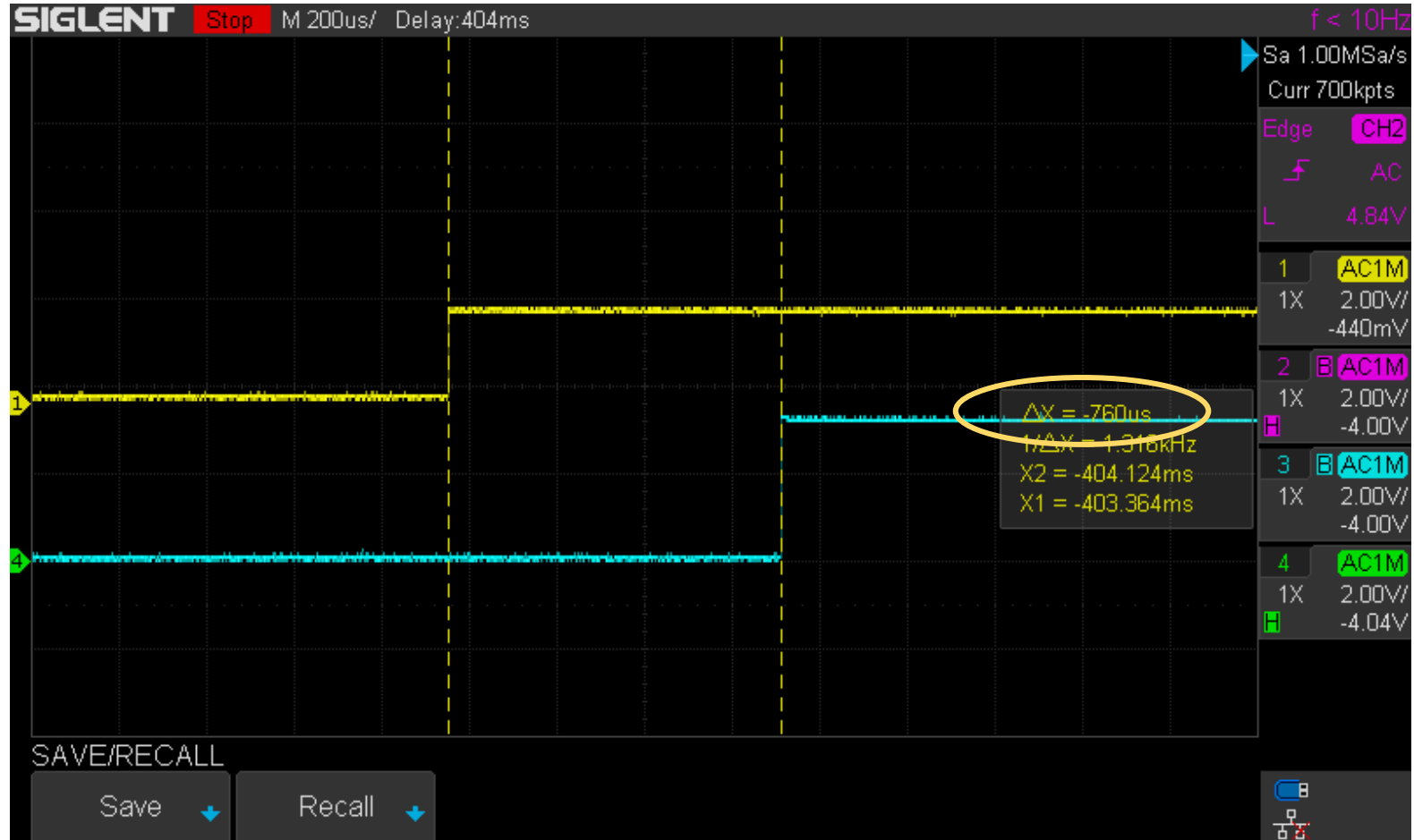
The image shows a Wireshark capture of Precision Time Protocol (PTP) messages. The main pane displays a list of captured packets, all of which are PTPv2 messages between source IP 172.98.168.1 and destination IP 172.98.168.7. The messages include Sync, Follow_Up, Delay_Req, Delay_Resp, and Announce. The packet details pane for a selected Sync Message (No. 96453) is expanded, showing the PTPv2 structure. The 'correction' field is highlighted with a green oval and shows a value of 0.000000 nanoseconds, indicating that no correction is being applied.

No.	Time	Source	Destination	Protocol	Length	Info
96442	7608.1785309...	172.98.168.1	172.98.168.7	PTPv2	86	Sync Message
96443	7608.1795266...	172.98.168.1	172.98.168.7	PTPv2	86	Follow_Up Message
96444	7608.2286190...	172.98.168.7	172.98.168.1	PTPv2	86	Delay_Req Message
96445	7608.2312756...	172.98.168.1	172.98.168.7	PTPv2	96	Delay_Resp Message
96446	7608.3042744...	172.98.168.1	172.98.168.7	PTPv2	86	Sync Message
96447	7608.3052765...	172.98.168.1	172.98.168.7	PTPv2	86	Follow_Up Message
96448	7608.3355111...	172.98.168.1	172.98.168.7	PTPv2	106	Announce Message
96449	7608.4290123...	172.98.168.1	172.98.168.7	PTPv2	86	Sync Message
96450	7608.4300027...	172.98.168.1	172.98.168.7	PTPv2	86	Follow_Up Message
96451	7608.4616382...	172.98.168.7	172.98.168.1	PTPv2	86	Delay_Req Message
96452	7608.4640373...	172.98.168.1	172.98.168.7	PTPv2	96	Delay_Resp Message
96453	7608.5540338...	172.98.168.1	172.98.168.7	PTPv2	86	Sync Message
96454	7608.5550271...	172.98.168.1	172.98.168.7	PTPv2	86	Follow_Up Message
96455	7608.5847853...	172.98.168.1	172.98.168.7	PTPv2	106	Announce Message
96456	7608.5948550...	172.98.168.7	172.98.168.1	PTPv2	86	Delay_Req Message
96457	7608.5965149...	172.98.168.1	172.98.168.7	PTPv2	96	Delay_Resp Message
96458	7608.6785017...	172.98.168.1	172.98.168.7	PTPv2	86	Sync Message
96459	7608.6794995...	172.98.168.1	172.98.168.7	PTPv2	86	Follow_Up Message
96460	7608.7593128...	172.98.168.7	172.98.168.1	PTPv2	86	Delay_Req Message
96461	7608.7610208...	172.98.168.1	172.98.168.7	PTPv2	96	Delay_Resp Message
96462	7608.8045204...	172.98.168.1	172.98.168.7	PTPv2	86	Sync Message
96463	7608.8055247...	172.98.168.1	172.98.168.7	PTPv2	86	Follow_Up Message
96464	7608.8355127...	172.98.168.1	172.98.168.7	PTPv2	106	Announce Message

```
Precision Time Protocol (IEEE1588)
  0000 .... = transportSpecific: 0x0
  ... 0000 = messageId: Sync Message (0x0)
  0000 .... = Reserved: 0
  ... 0010 = versionPTP: 2
  messageLength: 44
  subdomainNumber: 127
  Reserved: 0
  Flags: 0x063c
  - correction: 0.000000 nanoseconds
    correction: Ns: 0 nanoseconds
    correctionSubNs: 0 nanoseconds
  Reserved: 0
  ClockIdentity: 0x080011ffe21ed0a
  SourcePortID: 3
  sequenceId: 316
  control: Sync Message (0)
  logMessagePeriod: 127
```

- PTP is vulnerable to path asymmetry
- Any constant asymmetry will produce a time offset equal to half of the differential delay.
- Dynamic asymmetries will generate unpredictable errors thus impairing the synchronization precision
- Correction fields can be used by the TC to mitigate this

Without Correction (PPS)



Static Correction

ptp-zo_01.pcapng

File Bearbeiten Ansicht Navigation Aufzeichnen Analyse Statistiken Telephonie Wireless Tools Hilfe

Anzeigefilter anwenden ... <Ctrl-/>

No.	Time	Source	Destination	Protocol	Length	Info
21	0.441394766	172.98.168.5	224.0.1.129	PTPv2	102	Management Error Message (NO_SUCH_ID)
22	0.441394848	172.98.168.1	224.0.1.129	PTPv2	142	Management Message
23	0.441430304	172.98.168.4	224.0.1.129	PTPv2	102	Management Error Message (NO_SUCH_ID)
24	0.441465815	172.98.168.7	224.0.1.129	PTPv2	102	Management Error Message (NO_SUCH_ID)
25	0.539124679	172.98.168.1	172.98.168.7	PTPv2	86	Sync Message
26	0.540147368	172.98.168.1	172.98.168.7	PTPv2	86	Follow_Up Message
27	0.574826215	172.98.168.7	172.98.168.1	PTPv2	86	Delay_Req Message
28	0.577149408	172.98.168.1	172.98.168.7	PTPv2	96	Delay_Resp Message
29	0.663413817	172.98.168.1	172.98.168.7	PTPv2	106	Announce Message
30	0.663420535	172.98.168.1	172.98.168.7	PTPv2	86	Sync Message
31	0.663896354	172.98.168.1	172.98.168.7	PTPv2	86	Follow_Up Message

> Frame 28: 96 bytes on wire (768 bits), 96 bytes captured (768 bits) on interface enp6s0f1, id 0

> Ethernet II, Src: Tektroni_21:ed:0a (08:00:11:21:ed:0a), Dst: Mellanox_98:c8:85 (0c:42:a1:98:c8:85)

> Internet Protocol Version 4, Src: 172.98.168.1, Dst: 172.98.168.7

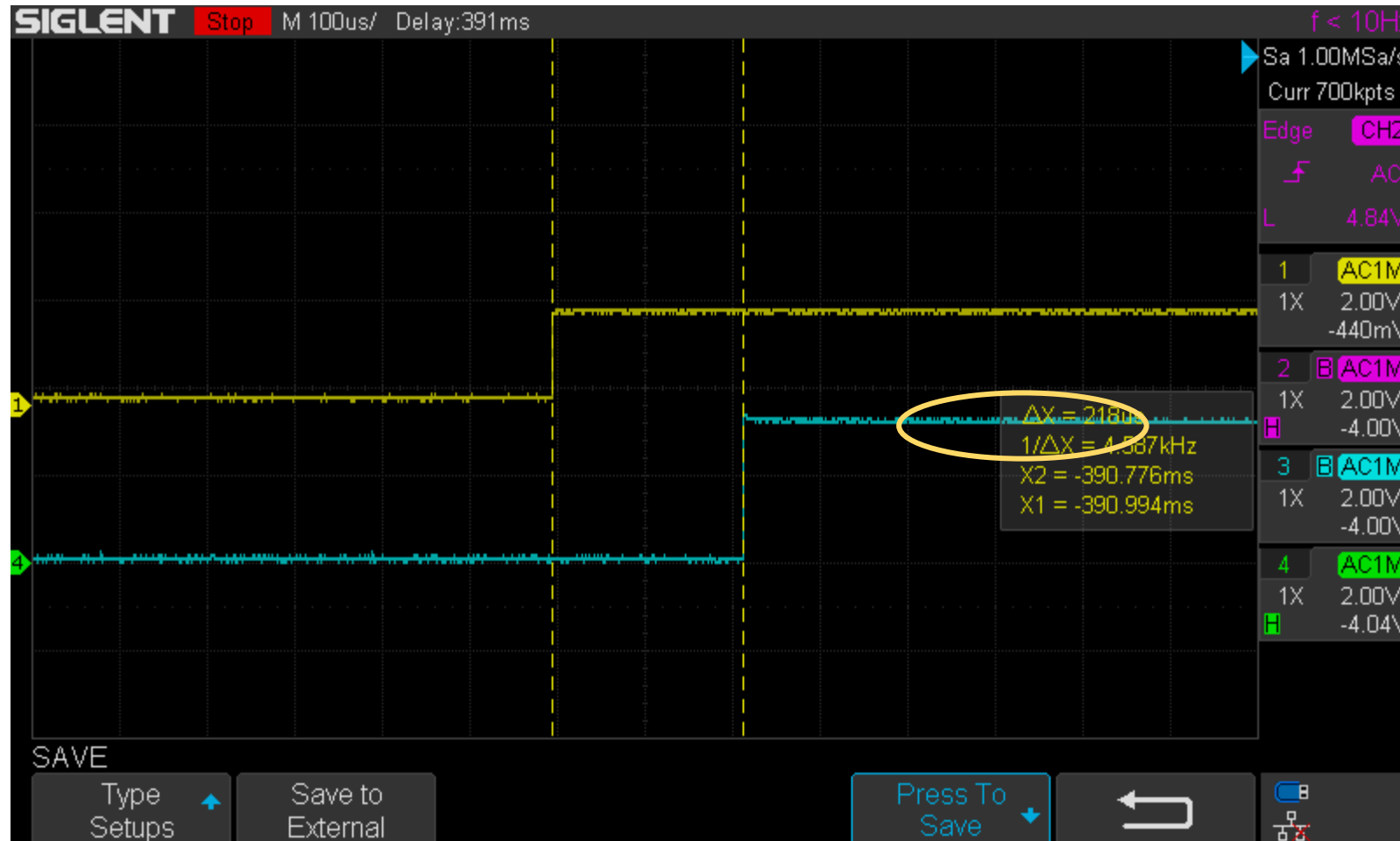
> User Datagram Protocol, Src Port: 320, Dst Port: 320

> Precision Time Protocol (IEEE1588)

- > 0000 = transportSpecific: 0x0
- 1001 = messageId: Delay_Resp Message (0x9)
- 0000 = Reserved: 0
- 0010 = versionPTP: 2
- messageLength: 54
- subdomainNumber: 127
- Reserved: 0
- > flags: 0x043c
- > correction: -150000,000000 nanoseconds
- Reserved: 0
- > ClockIdentity: 0x080011ffffe21ed0a
- SourcePortID: 3
- sequenceId: 45111
- control: Delay_Resp Message (3)
- logMessagePeriod: 127
- receiveTimestamp (seconds): 1643186007
- receiveTimestamp (nanoseconds): 982209904
- requestingSourcePortIdentity: 0x0c42a1ffffe98c885
- requestingSourcePortId: 1

- Here, the correction field is manually inserted, using the delayAsymmetry property of ptp4l
- This can be used to fix constant asymmetry

Release 15 results (with static correction)



Dynamic correction

Datei Bearbeiten Ansicht Navigation Aufzeichnen Analyse Statistiken Telephonie Wireless Tools Hilfe

Anzeigefilter anwenden ... <Ctrl-/>

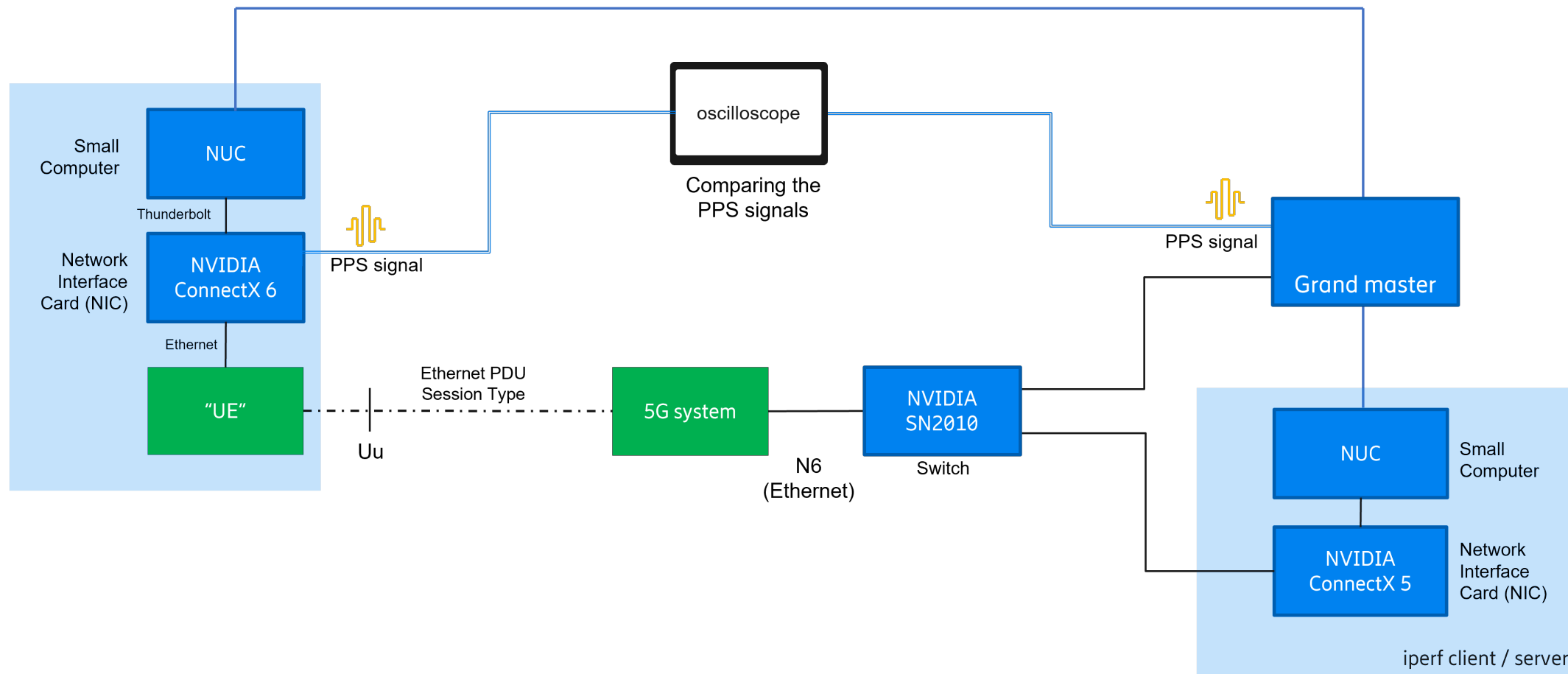
No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000	172.20.2.5	172.20.2.1	PTPv2	86	Delay_Req Message
2	0.001770	172.20.2.1	172.20.2.5	PTPv2	96	Delay_Resp Message
3	0.016607	172.20.2.5	172.20.2.1	PTPv2	86	Delay_Req Message
4	0.018768	172.20.2.1	172.20.2.5	PTPv2	96	Delay_Resp Message
5	0.055773	172.20.2.1	172.20.2.5	PTPv2	86	Sync Message
6	0.056771	172.20.2.1	172.20.2.5	PTPv2	86	Follow_Up Message
7	0.070477	172.20.2.5	172.20.2.1	ICMP	98	Echo (ping) request id=0x0030, seq
8	0.072782	172.20.2.1	172.20.2.5	ICMP	98	Echo (ping) reply id=0x0030, seq
9	0.153872	172.20.2.5	172.20.2.1	PTPv2	86	Delay_Req Message
10	0.155522	172.20.2.1	172.20.2.5	PTPv2	96	Delay_Resp Message

<

> Frame 4: 96 bytes on wire (768 bits), 96 bytes captured (768 bits)
> Ethernet II, Src: Tektroni_21:ed:0a (08:00:11:21:ed:0a), Dst: Mellanox_98:c8:85 (0c:42:a1:98:c8:85)
> Internet Protocol Version 4, Src: 172.20.2.1, Dst: 172.20.2.5
> User Datagram Protocol, Src Port: 320, Dst Port: 320
v Precision Time Protocol (IEEE1588)
 > 0000 = transportSpecific: 0x0
 1001 = messageId: Delay_Resp Message (0x9)
 0000 = Reserved: 0
 0010 = versionPTP: 2
 messageLength: 54
 subdomainNumber: 127
 Reserved: 0
 > flags: 0x043c
 > correction: 737120,000000 nanoseconds
 Reserved: 0
 > ClockIdentity: 0x080011fffe21ed0a
 SourcePortID: 3
 sequenceId: 15481
 control: Delay_Resp Message (3)
 logMessagePeriod: 127
 receiveTimestamp (seconds): 1643227223
 receiveTimestamp (nanoseconds): 230709712
 requestingSourcePortIdentity: 0x0c42a1fffe98c885
 requestingSourcePortId: 1

- Ericsson URLLC system can detect PTP packets and use the correction fields to signal residence time, thus acting as a TC

Experiment setup



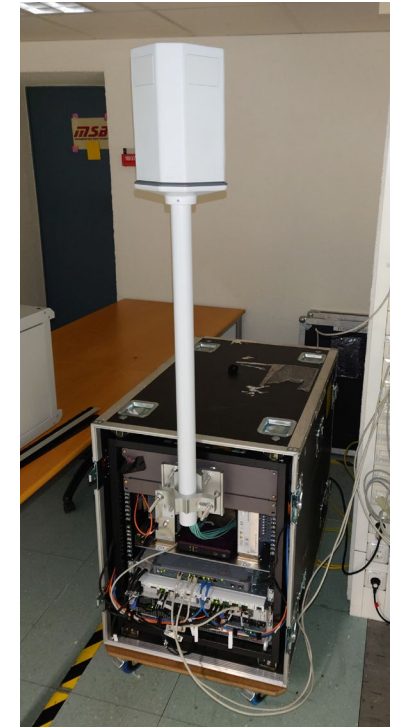
URLLC test network (Rel. 16 + 17 features)



Location	Ericsson Aachen
Setup type	Portable indoor setup (OTA)
Core	NR-SA (Rel. 16 + 17)
Supported band	mmW (28GHz): 27.5-28.3 GHz
Available bandwidth	1-2x 100MHz
MIMO support	2DL/2 UL
Features	TSN 2ms RTT URLLC slice vs eMBB

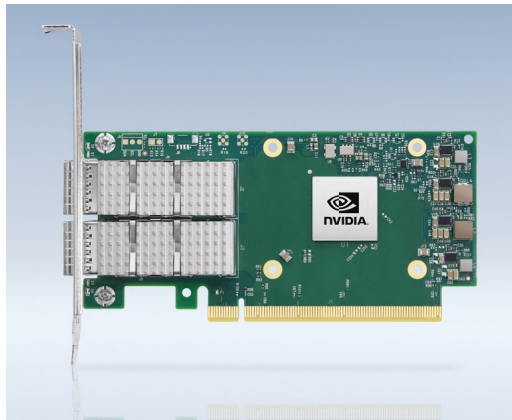


gNodeB



UE

Hardware components



Nvidia Mellanox ConnectX6 DX

- Dual 100 Gbps interface
- Supports high (single nanosecond) PTP precession
- Outputs PPS signal



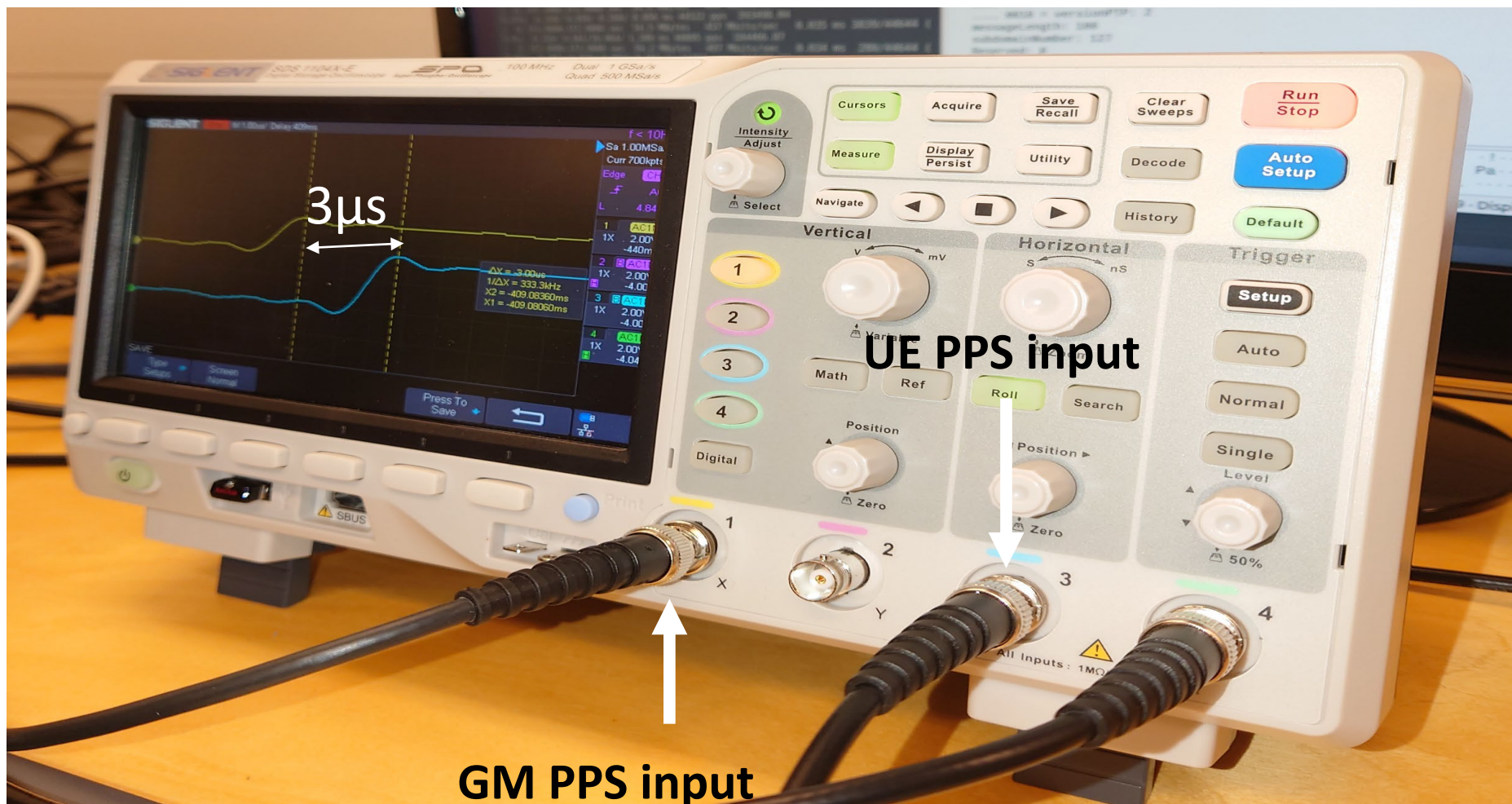
Nvidia SN 2010
Ethernet switch



Tektroniks SPG8000a

- PTP (IEEE 1588-2008)
- SMPTE ST 2059-2 profile in Unicast mode

Oscilloscope measurements



Test 1: Measurements without timing assistance or PTP client's parameters tweaking



The general parameters of the test:

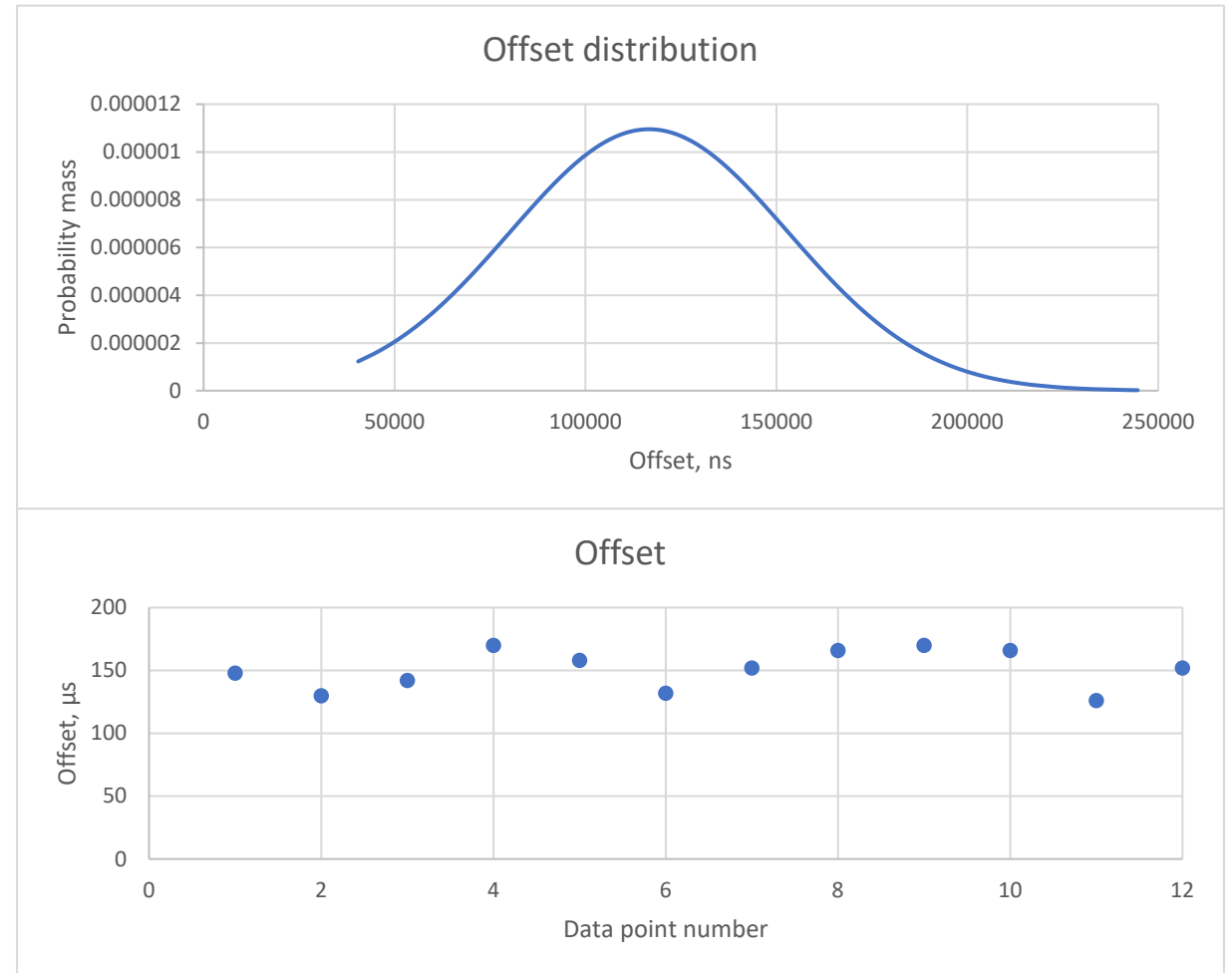
- Residence time provided: No
- PTP servo used: Linear regression
- Advanced servo parameters tweaking: No
- Number of data points: 1577

The main results are the following:

- Average PTP accuracy: 116653 ns ($\sim 117 \mu\text{s}$)
- Median PTP accuracy: 116036 ns ($\sim 117 \mu\text{s}$)

PPS measurements results:

- Number of data points: 12
- Average offset: 152 μs



Test 2: Measurements with timing assistance and PTP client's parameters tweaking



The general parameters of the test:

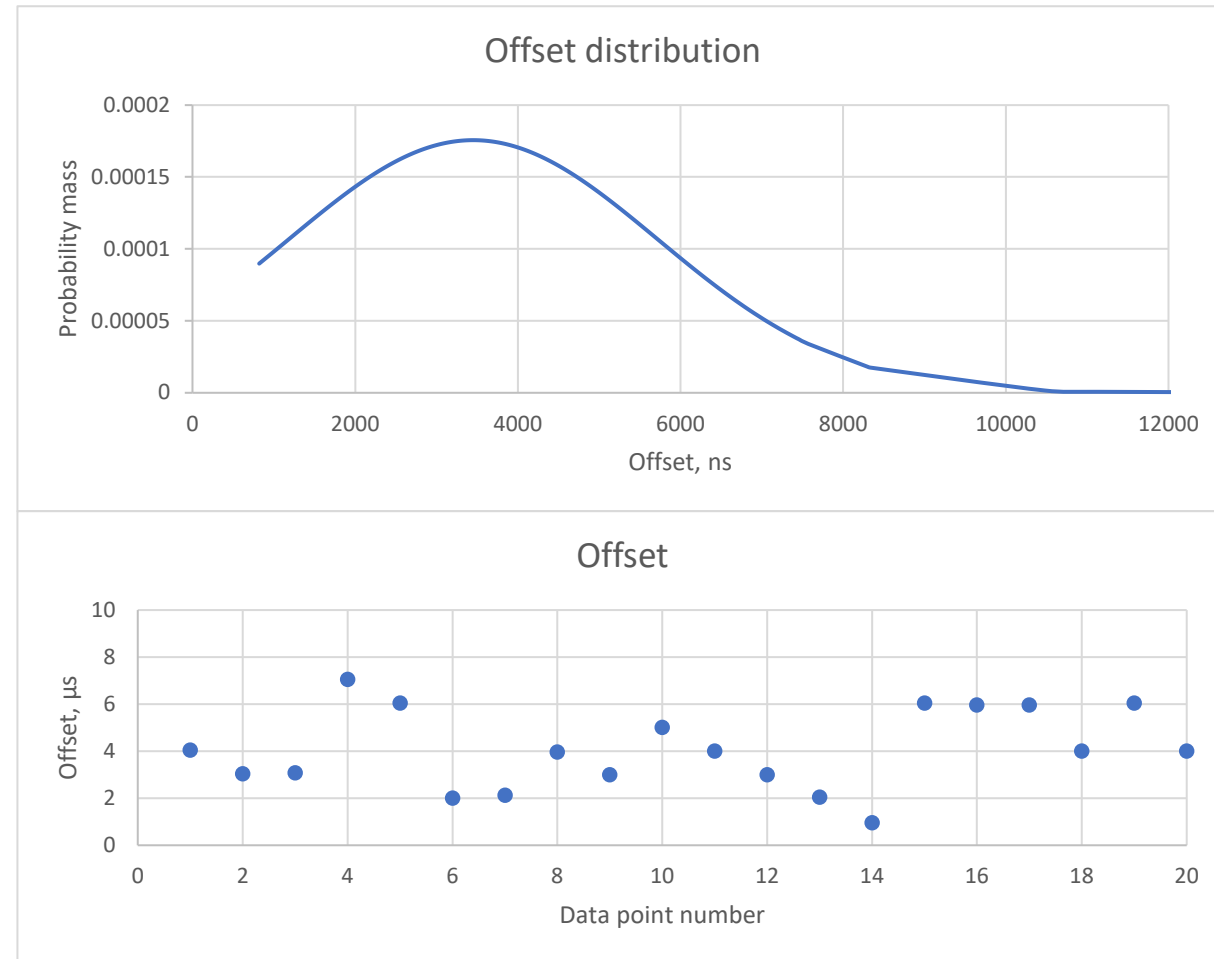
- Residence time provided: Yes
- PTP servo used: PI
- Advanced servo parameters tweaking: Yes
- Number of data points: 932

The main results are the following:

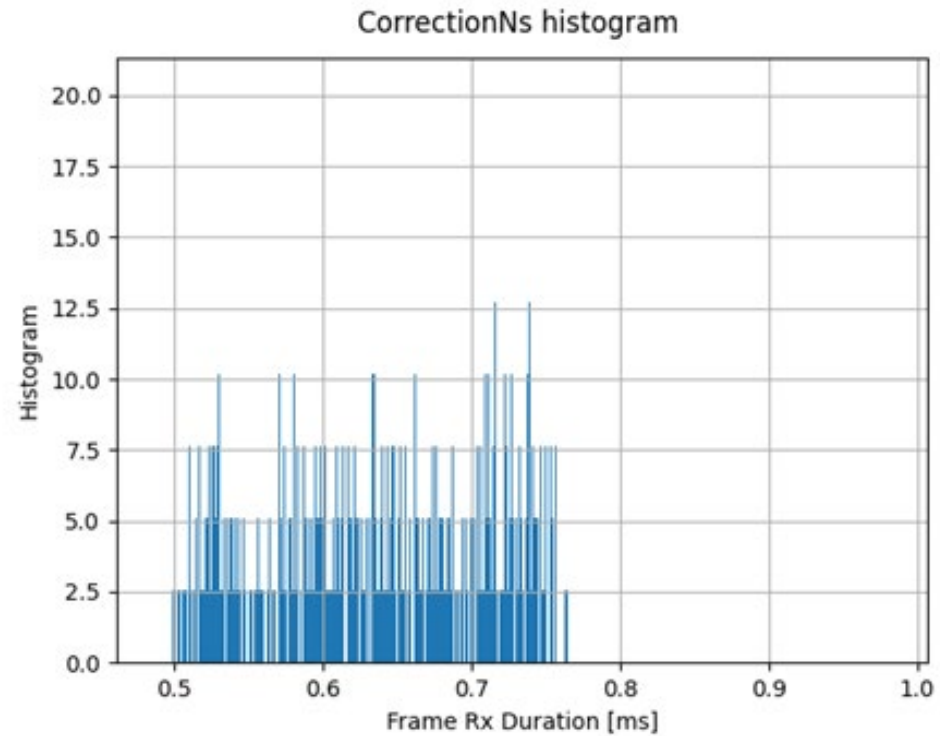
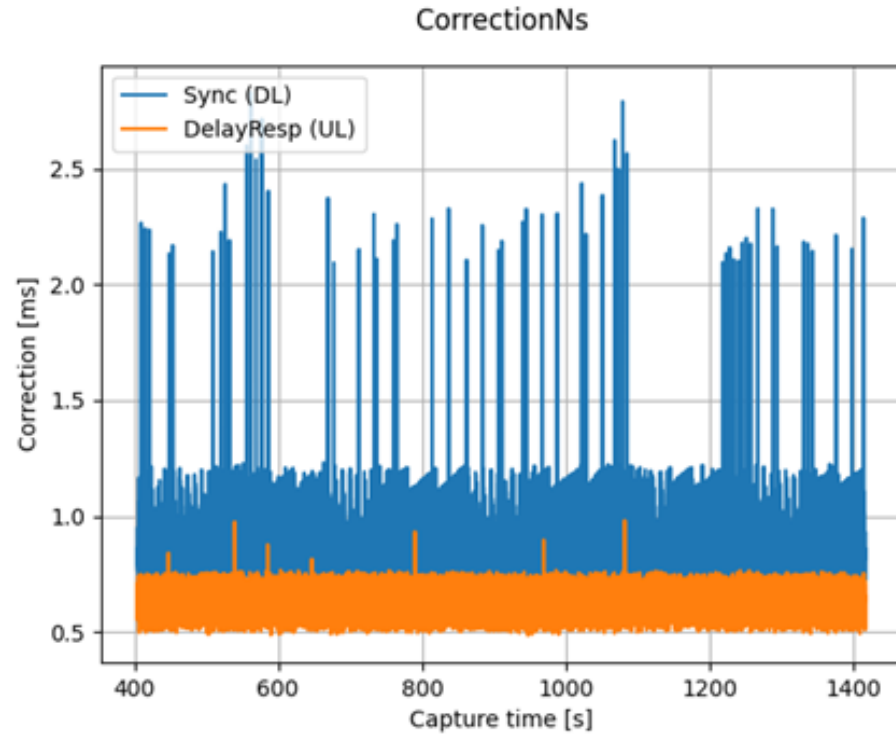
- Average PTP accuracy: 3451 ns ($\sim 3,5 \mu\text{s}$)
- Median PTP accuracy: 2832 ns ($\sim 2,8 \mu\text{s}$)

PPS measurements results:

- Number of data points: 20
- Average offset: 4,066 μs



Test 2: Measurements with timing assistance and PTP client's parameters tweaking



Residence time and a histogram of residence time reported by the testbed in correction fields over time for Test 2

Test 3: Measurements with timing assistance but no PTP client's parameters tweaking



The general parameters of the test:

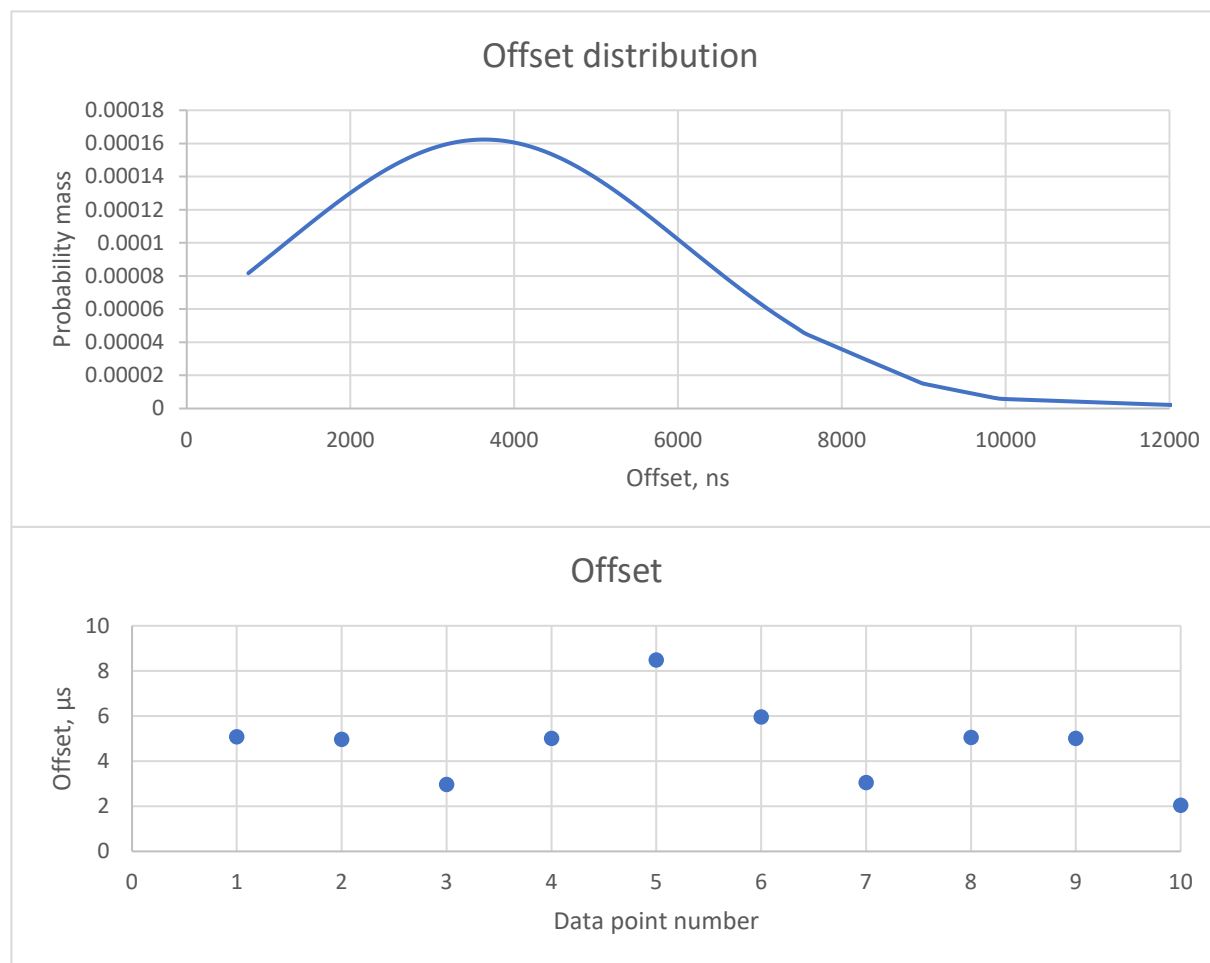
- Residence time provided: Yes
- PTP servo used: Linear regression
- Advanced servo parameters tweaking: No
- Number of data points: 449

The main results are the following:

- Average PTP accuracy: 3633 ns ($\sim 3,6 \mu\text{s}$)
- Median PTP accuracy: 3106 ns ($\sim 3,1 \mu\text{s}$)

PPS measurements results:

- Number of data points: 10
- Average offset: 4,756 μs



Test 4: Measurements under load - in the presence of network congestion

The general parameters of the test:

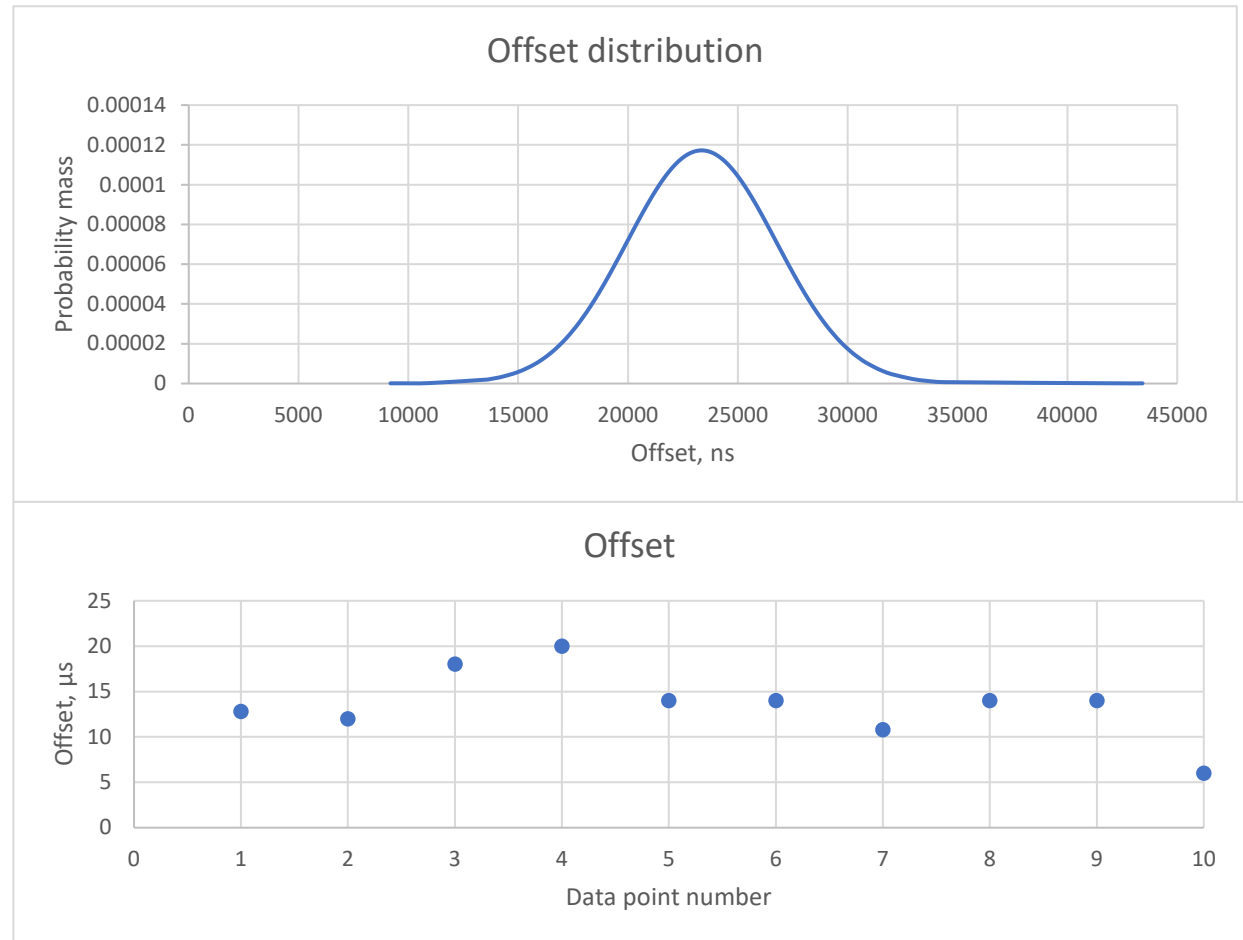
- Residence time provided: Yes
- PTP servo used: Linear regression
- Advanced servo parameters tweaking: No
- Number of data points: 737

The main results are the following:

- Average PTP accuracy: 23358 ns (~23,4 μ s)
- Median PTP accuracy: 23350 ns (~23,4 μ s)

PPS measurements results.

- Number of data points: 10
- Average offset: 13,56 μ s

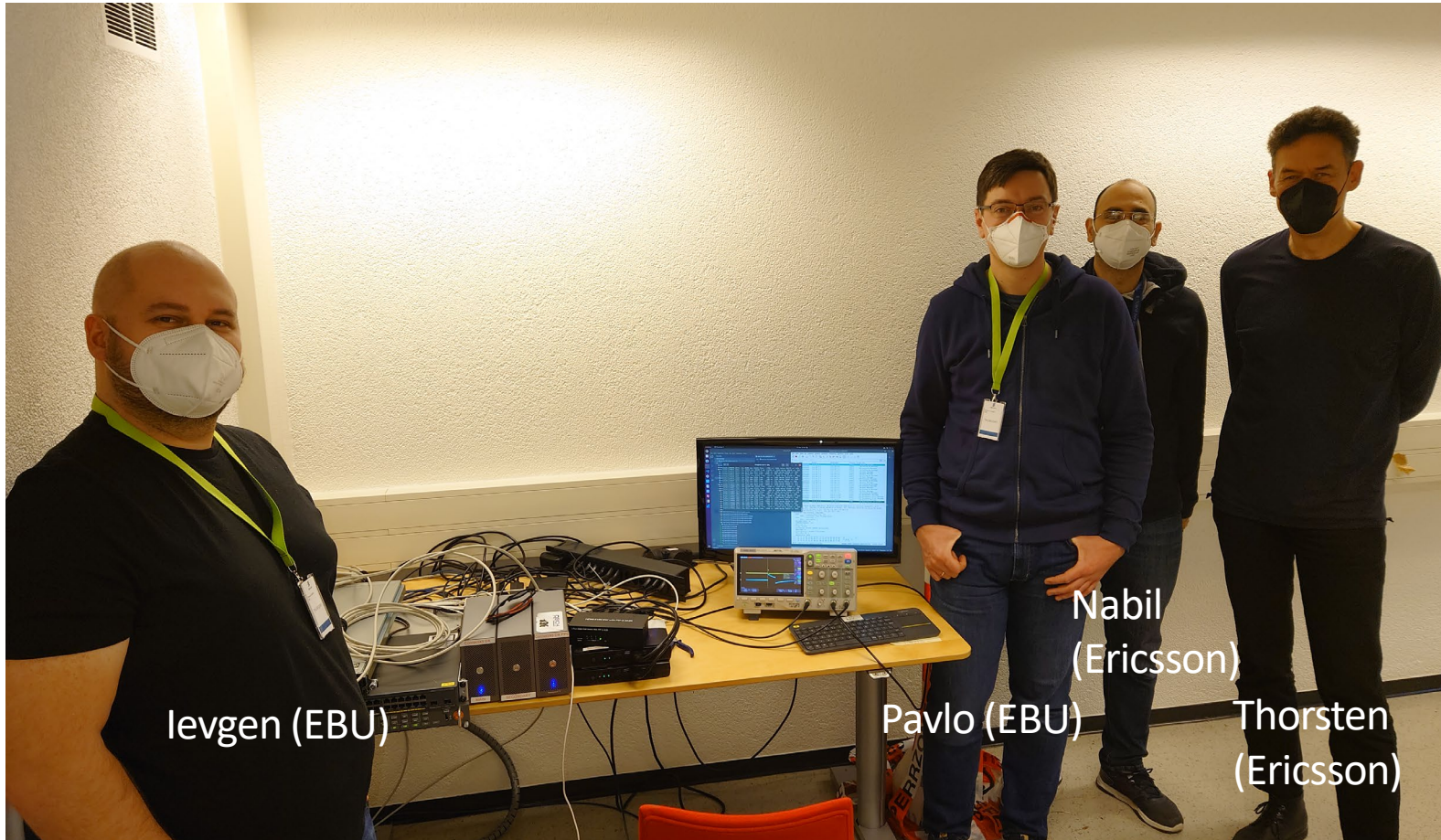


Conclusions



- Synchronization accuracy of less than 4 μs can be achieved with residence time measured and reported by the 5G system compared to $\sim 120\text{-}150 \mu\text{s}$ achieved with the TSN features disabled
- In the presence of network congestion of 80-90% of available bandwidth the accuracy degrades to $\sim 24 \mu\text{s}$

Team



Ievgen (EBU)

Nabil (Ericsson)

Pavlo (EBU)

Thorsten (Ericsson)

+ Not on the picture -
Thomas Kernen (NVIDIA)
and Ericsson support team



Thank You Or Any Questions?

Presenting: Ievgen Kostiukevych (EBU), Pavlo Kondratenko (EBU)

Co-Authors: Thorsten Lohmar (Ericsson), Mohamed Nabil Ibrahim (Ericsson), Thomas Kernen (NVIDIA)



IP SHOWCASE