

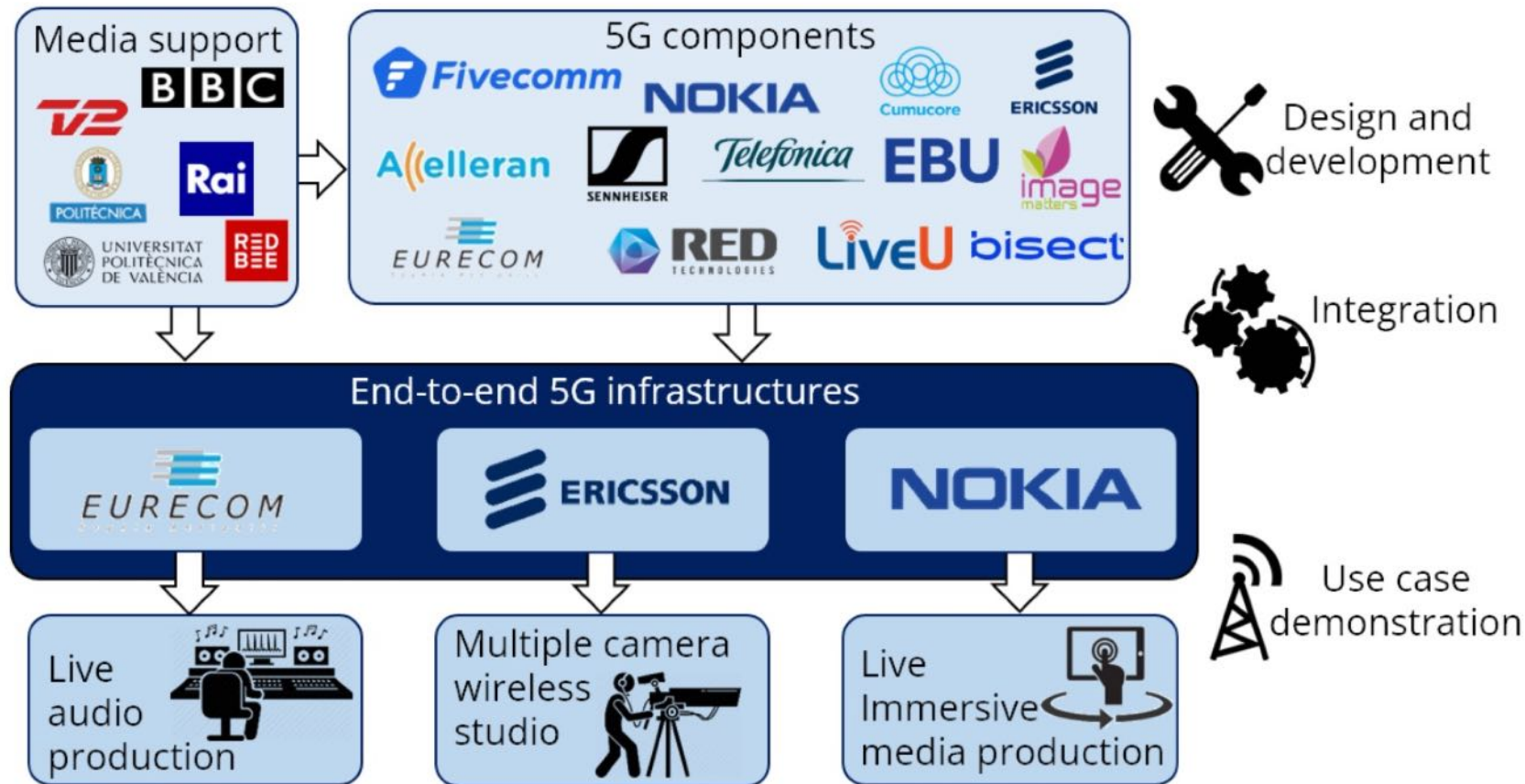
Practicalities and analysis of using PTP over 5G systems with dedicated time synchronization support for media production

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

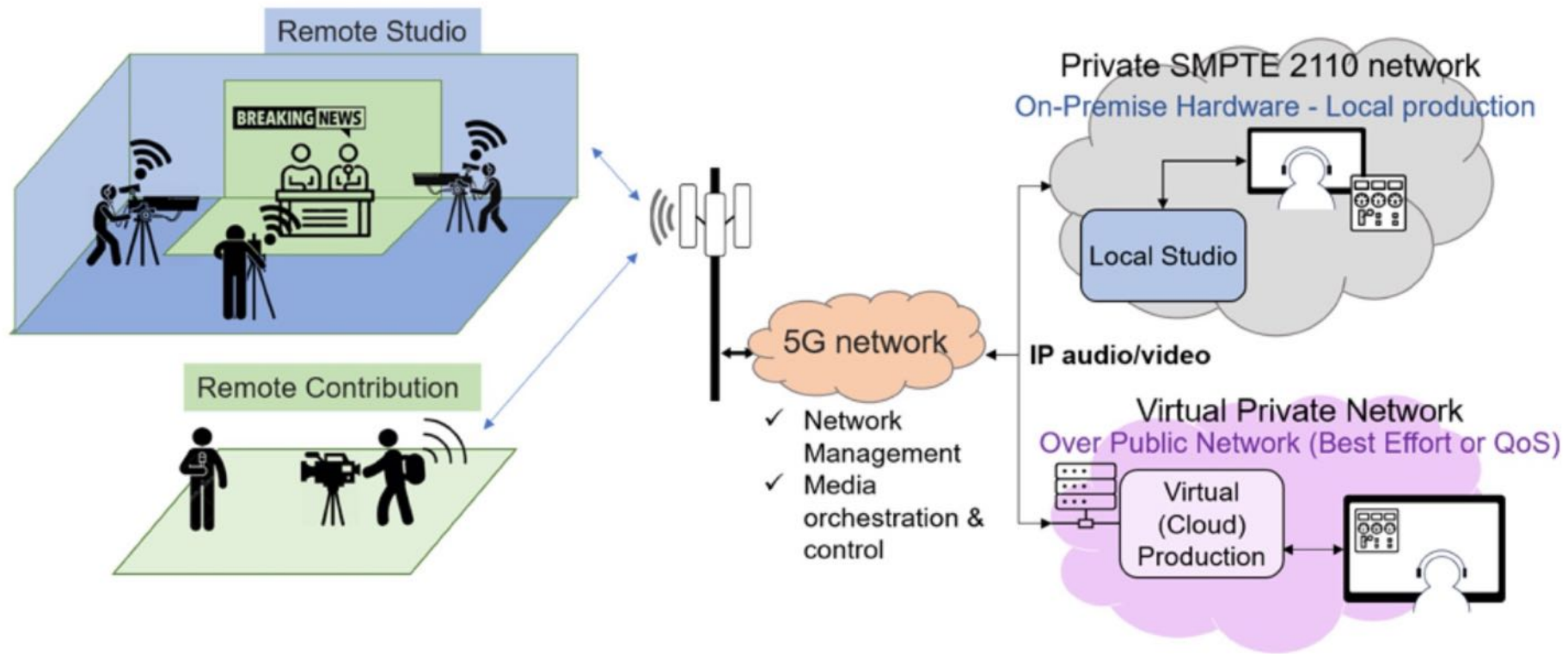
Co-Authors: Thorsten Lohmar (Ericsson), Mohamed Nabil Ibrahim (Ericsson), Thomas Kernen (NVIDIA)



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

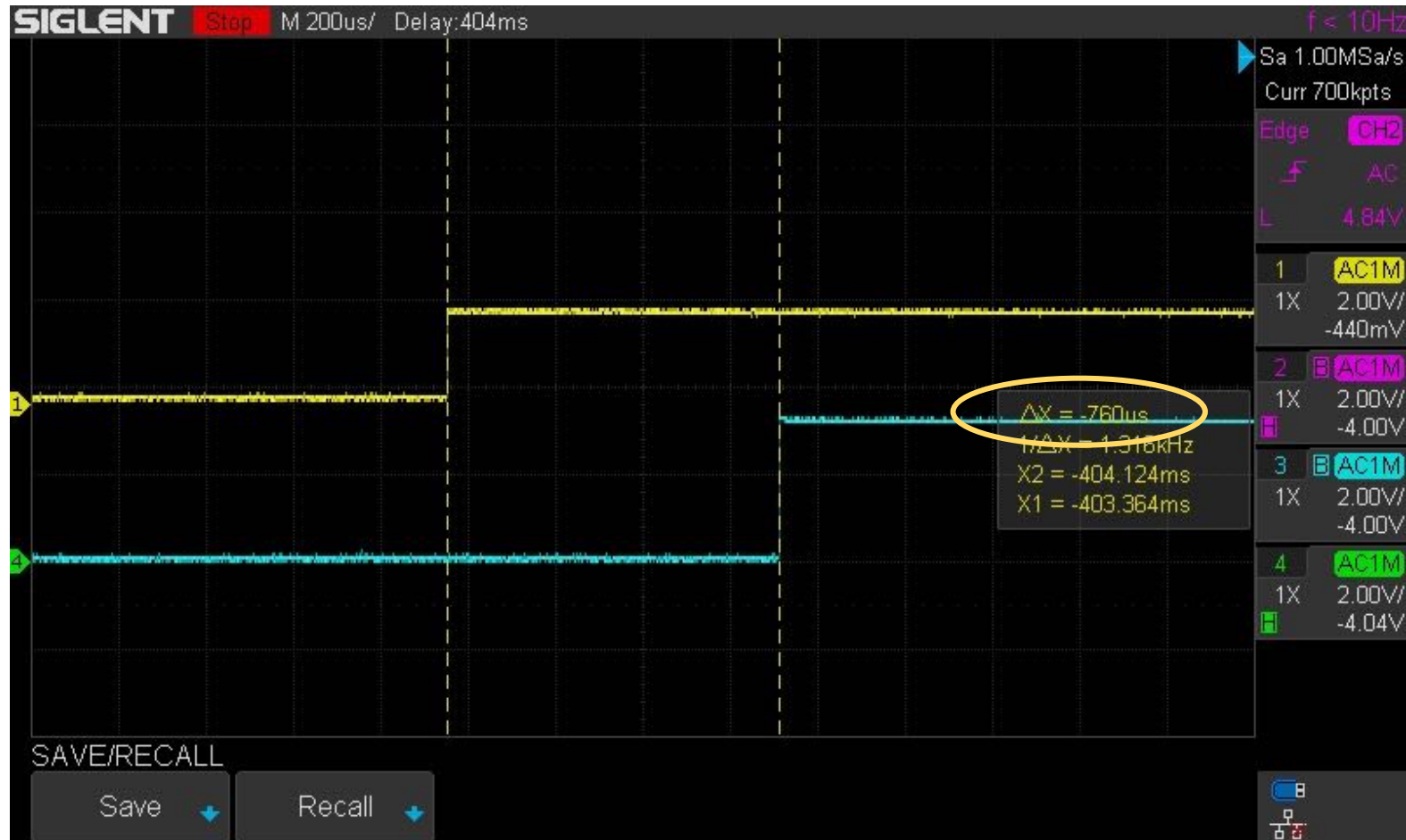
The image shows a Wireshark capture of Precision Time Protocol (PTP) messages. The main pane displays a list of captured packets, and the lower pane shows the detailed view of a selected PTPv2 Sync Message. The 'correction' field is highlighted with a green oval, showing a value of 0.000000 nanoseconds.

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

Datei 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

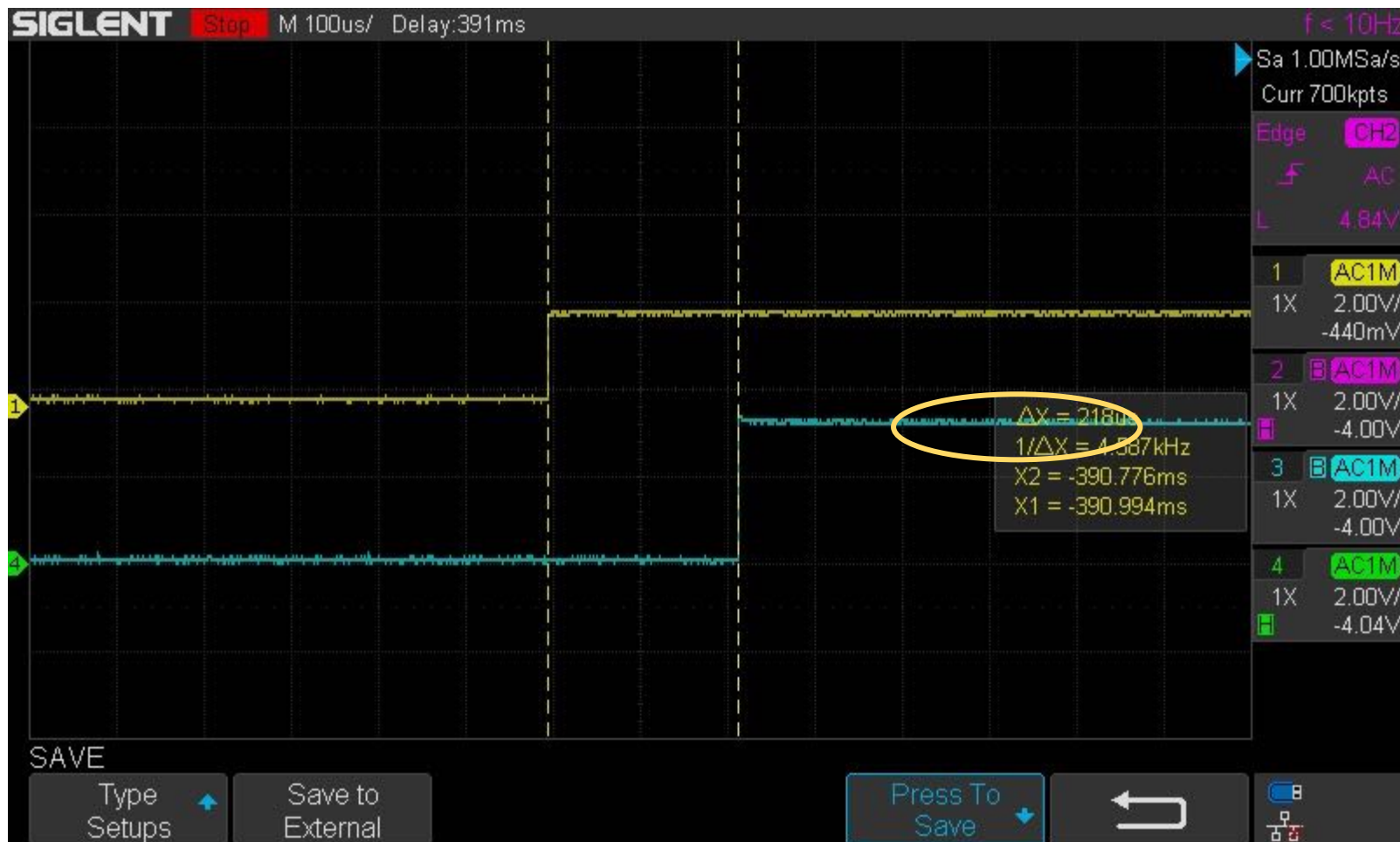
> User Datagram Protocol, Src Port: 320, Dst Port: 320

▼ 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-/>

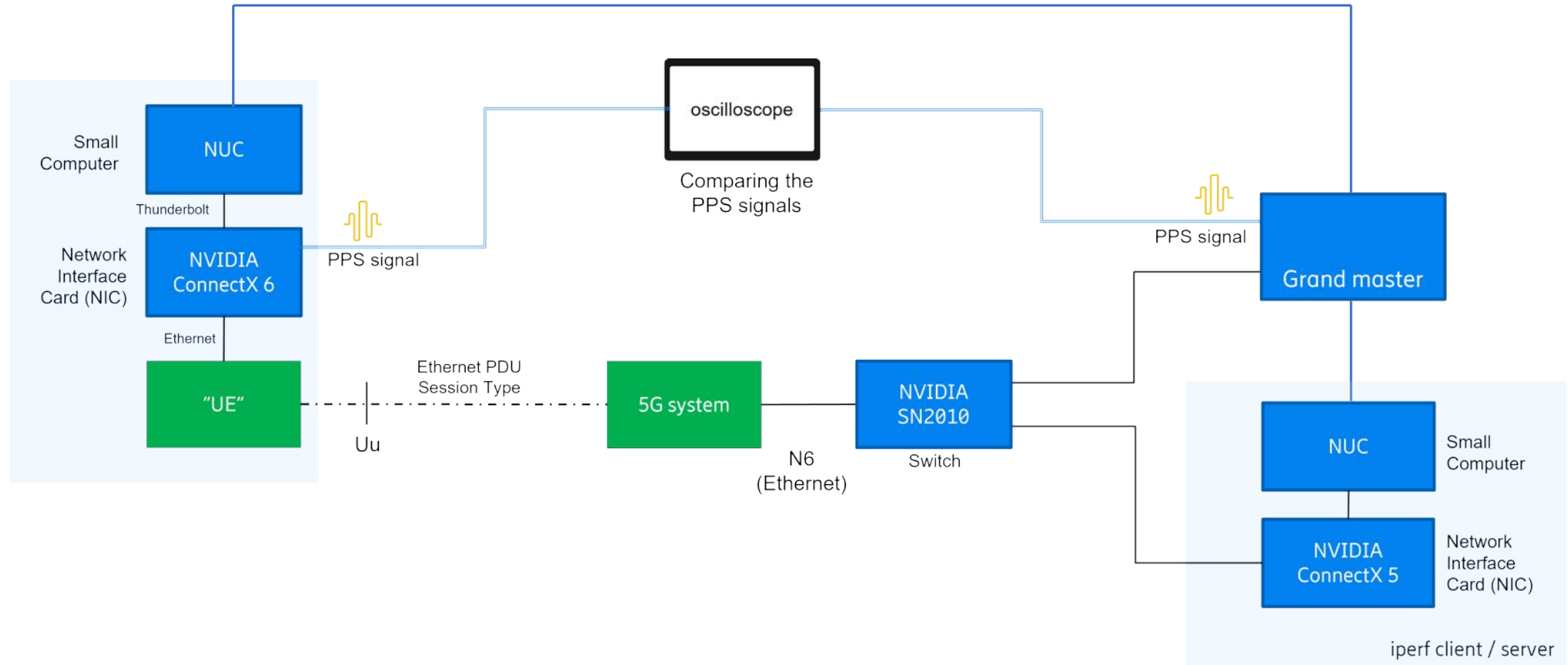
No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000	172.20.2.5	172.20.2.1	PTPv2	86	Delay_Req Message
2	0.001770	172.20.2.1	172.20.2.5	PTPv2	96	Delay_Resp Message
3	0.016607	172.20.2.5	172.20.2.1	PTPv2	86	Delay_Req Message
4	0.018768	172.20.2.1	172.20.2.5	PTPv2	96	Delay_Resp Message
5	0.055773	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

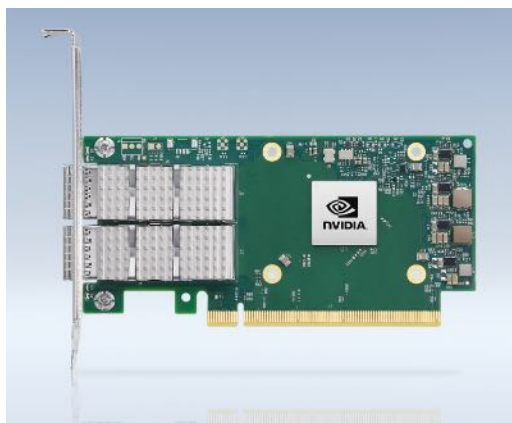


gNodeB



UE

Hardware components



Nvidia Mellanox ConnectX6 DX

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



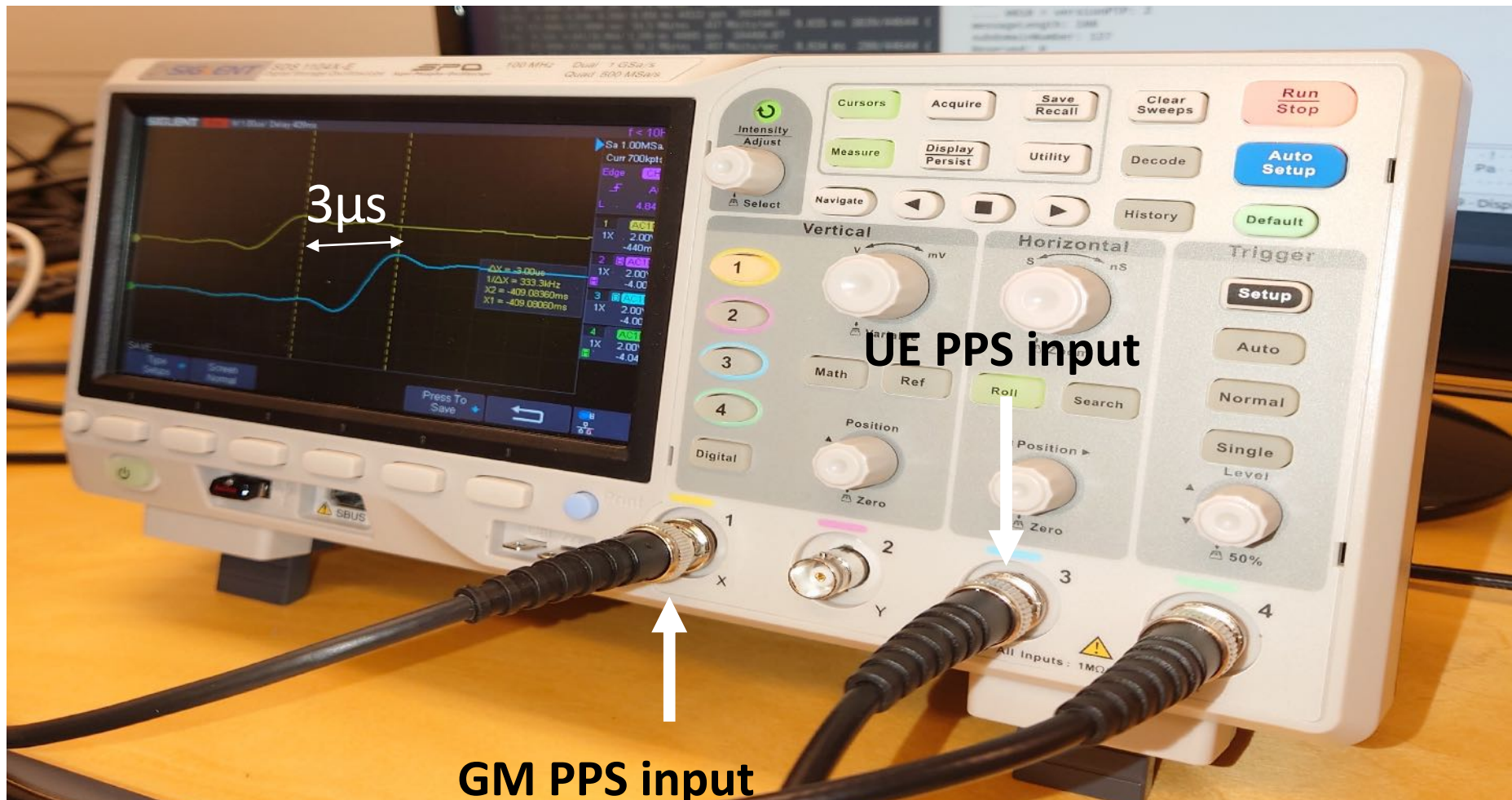
Nvidia SN 2010
Ethernet switch



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:

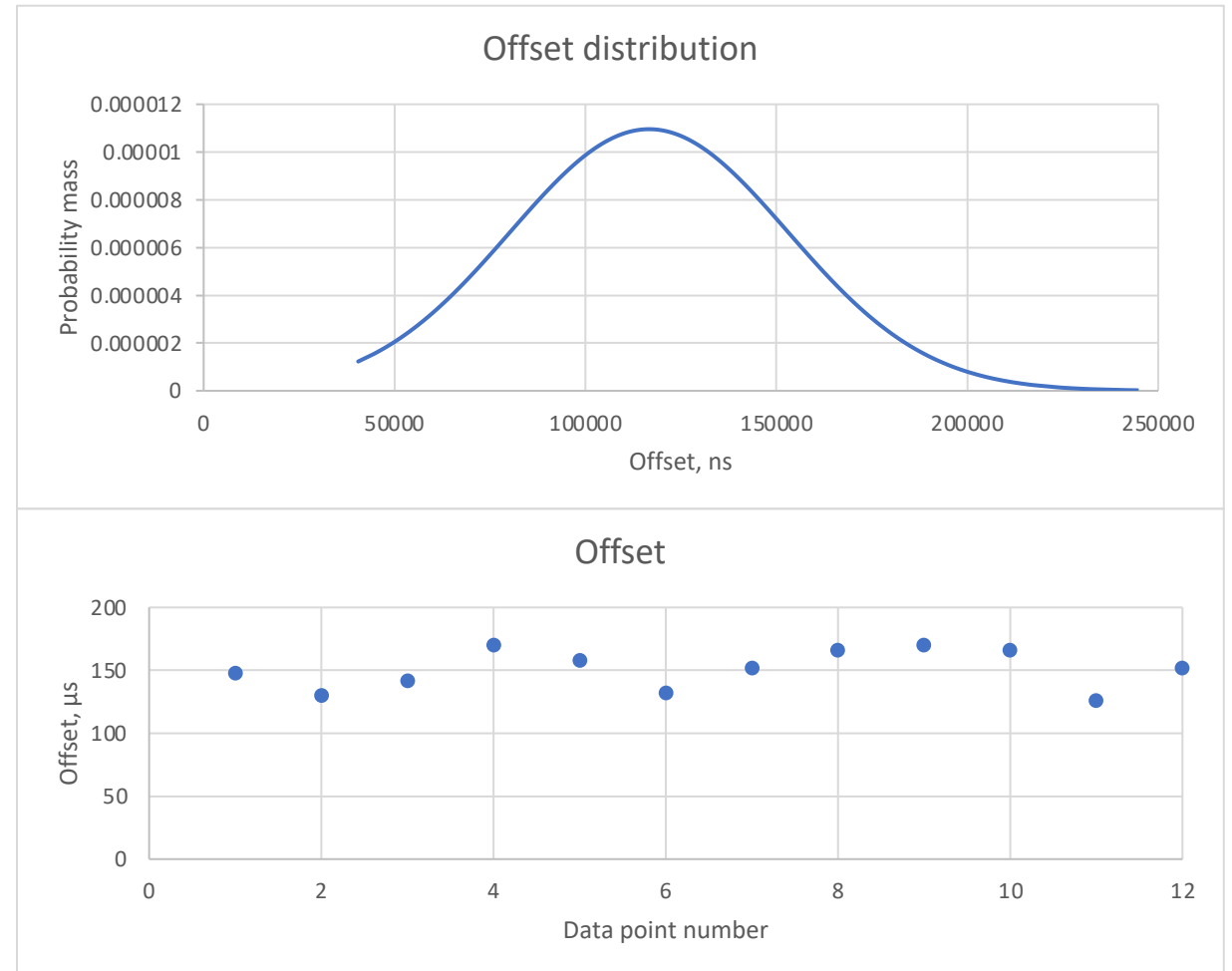
- Residence time provided: No
- PTP servo used: Linear regression
- Advanced servo parameters tweaking: No
- Number of data points: 1577

The main results are the following:

- Average PTP accuracy: 116653 ns (~117 μ s)
- Median PTP accuracy: 116036 ns (~117 μ s)

PPS measurements results:

- Number of data points: 12
- Average offset: 152 μ s



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



The general parameters of the test:

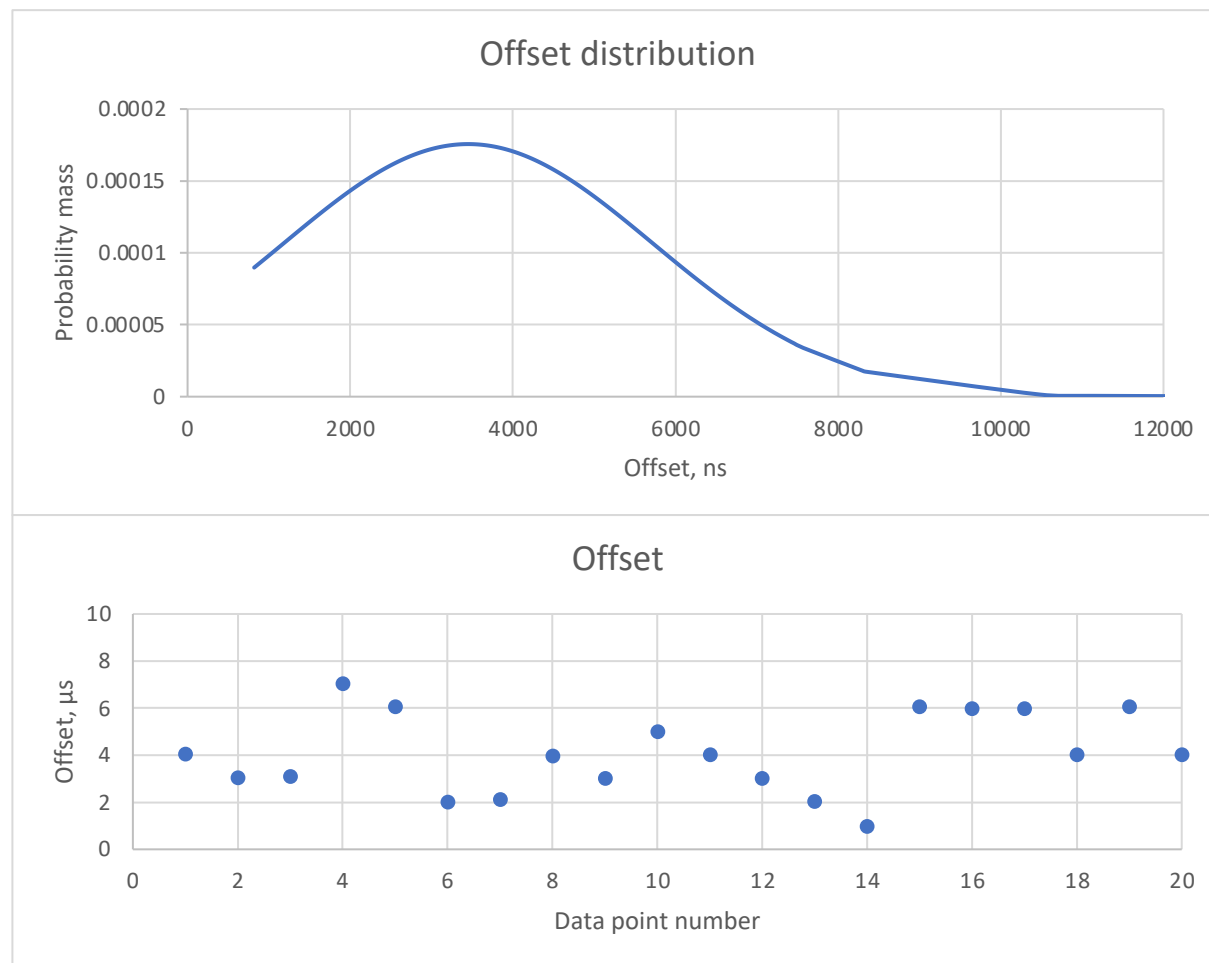
- Residence time provided: Yes
- PTP servo used: PI
- Advanced servo parameters tweaking: Yes
- Number of data points: 932

The main results are the following:

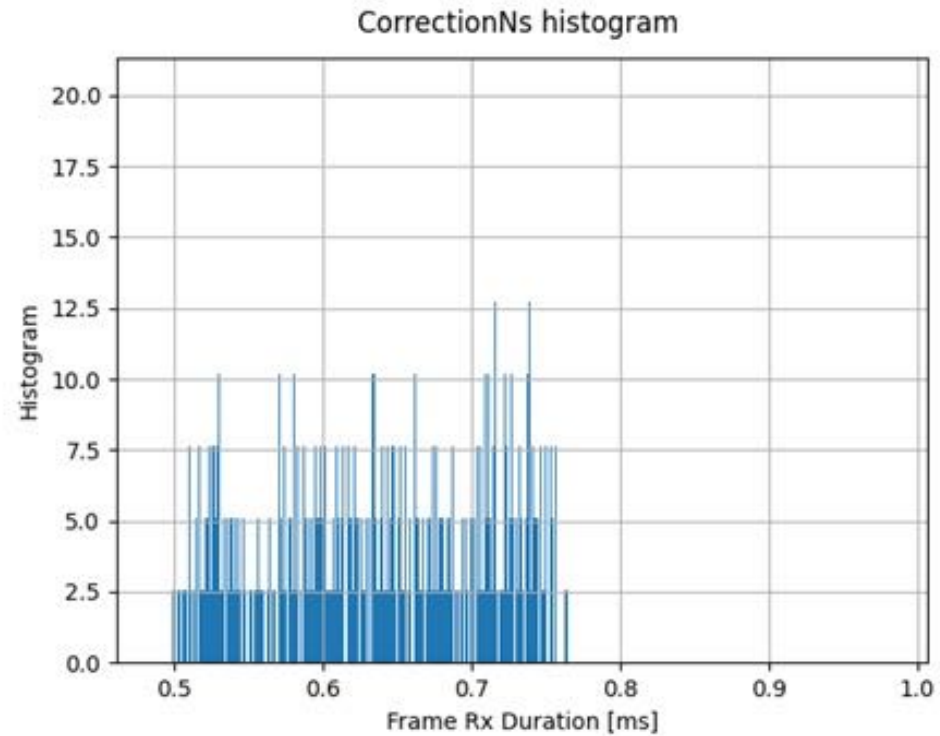
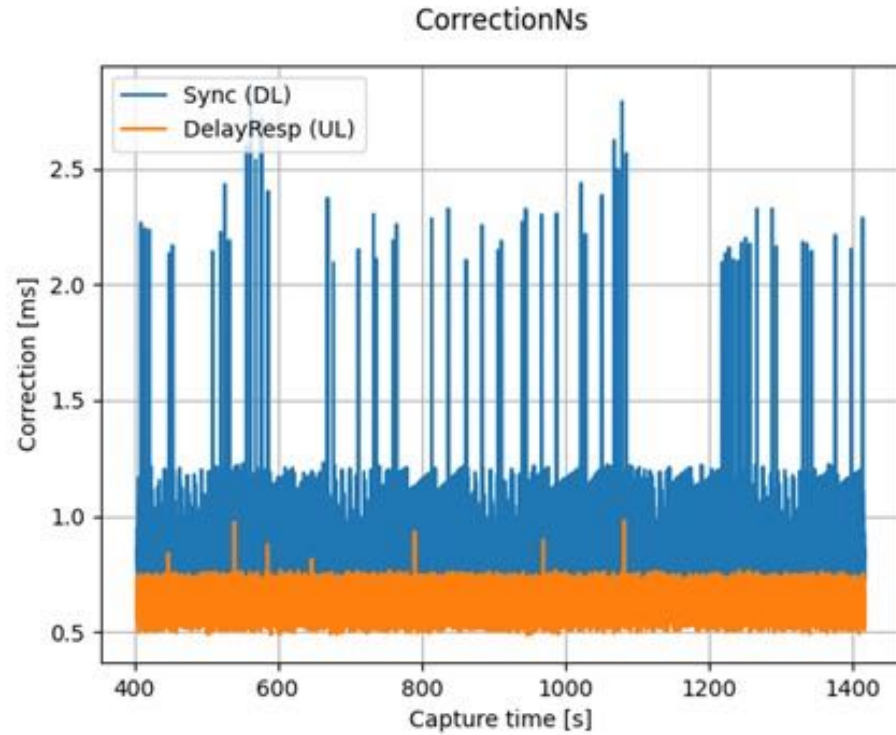
- Average PTP accuracy: 3451 ns ($\sim 3,5 \mu\text{s}$)
- Median PTP accuracy: 2832 ns ($\sim 2,8 \mu\text{s}$)

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:

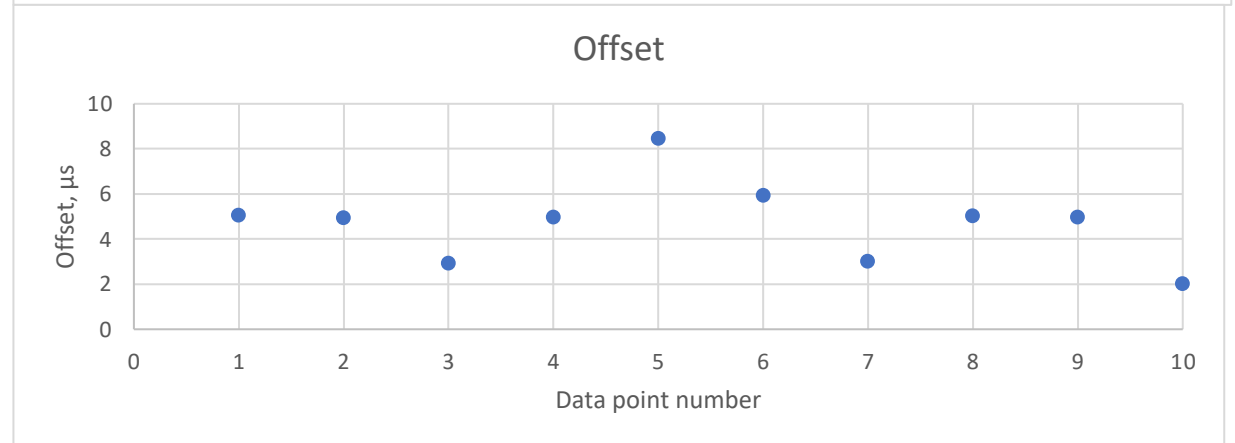
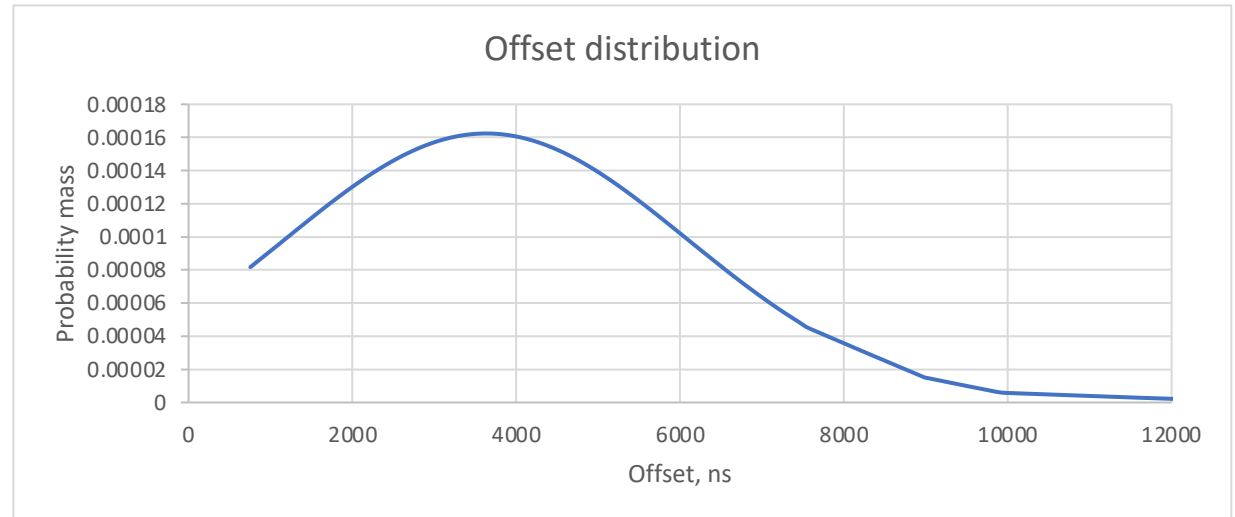
- Residence time provided: Yes
- PTP servo used: Linear regression
- Advanced servo parameters tweaking: No
- Number of data points: 449

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:

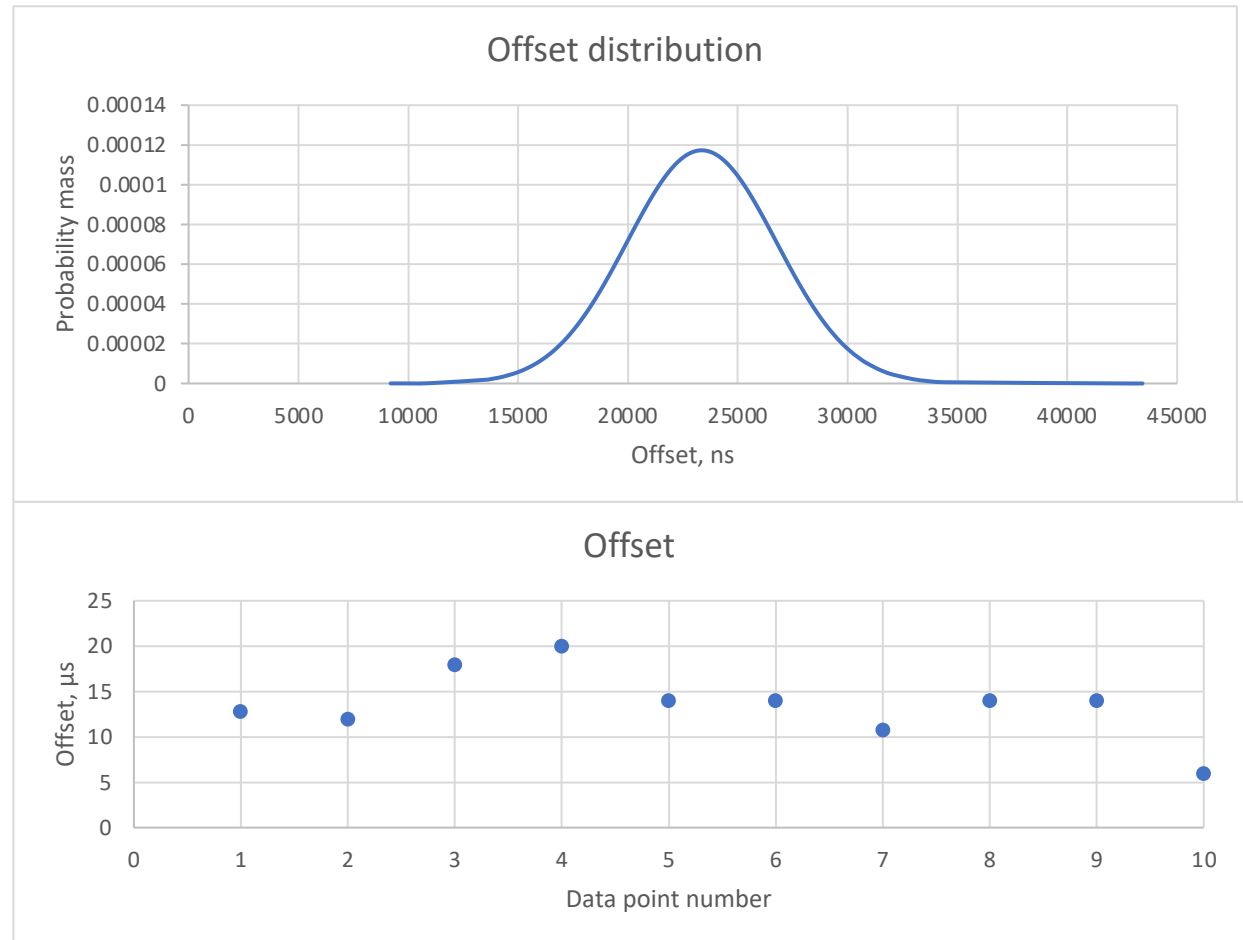
- Residence time provided: Yes
- PTP servo used: Linear regression
- Advanced servo parameters tweaking: No
- Number of data points: 737

The main results are the following:

- Average PTP accuracy: 23358 ns ($\sim 23,4 \mu\text{s}$)
- Median PTP accuracy: 23350 ns ($\sim 23,4 \mu\text{s}$)

PPS measurements results.

- Number of data points: 10
- Average offset: $13,56 \mu\text{s}$

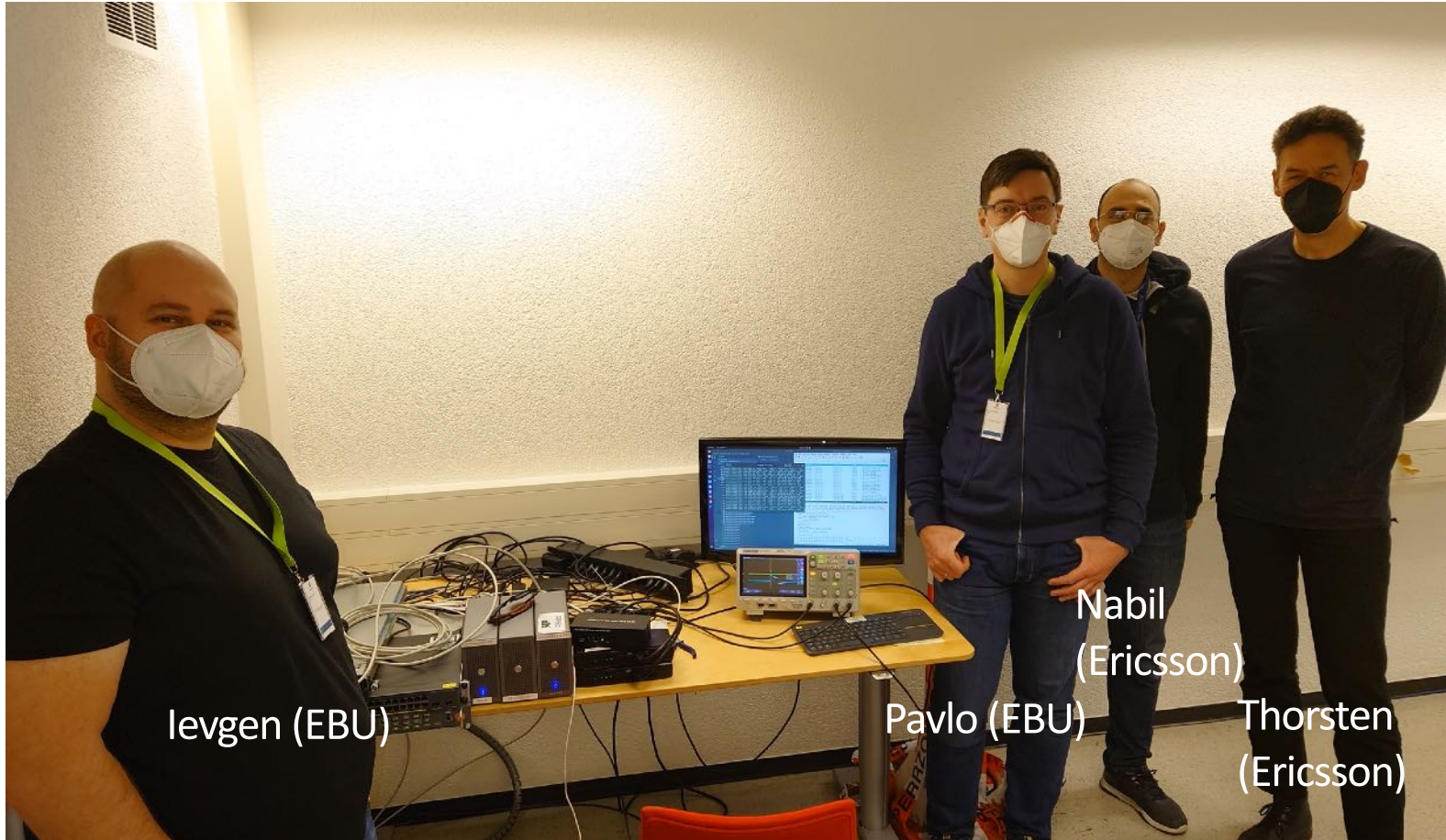


Conclusions



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

Team



Ievgen (EBU)

Pavlo (EBU)

Nabil
(Ericsson)

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)

