

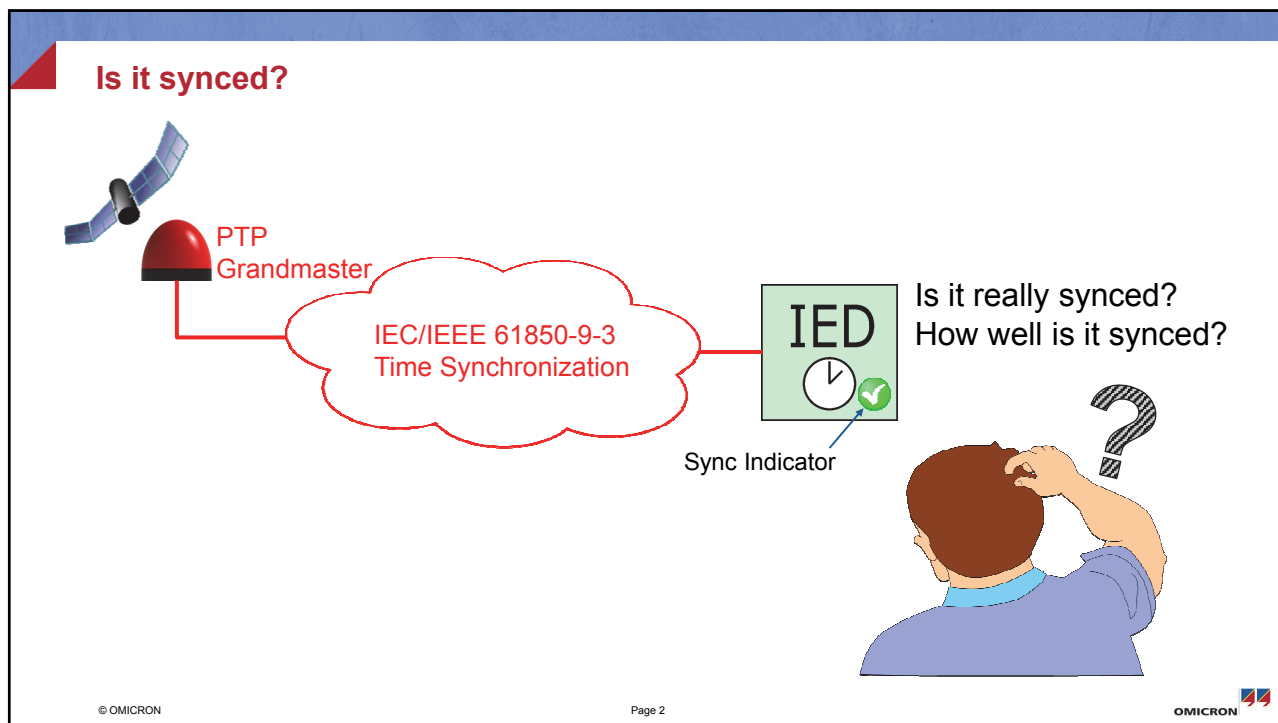
OMICRON

# IEC/IEEE 61850-9-3 Testing PTP time synchronization

Bernhard Baumgartner, OMICRON, Klaus, Austria

4 May 2017

## Is it synced?



PTP  
Grandmaster

IEC/IEEE 61850-9-3  
Time Synchronization

IED

Sync Indicator

Is it really synced?  
How well is it synced?

© OMICRON

Page 2

OMICRON

## Are these IEDs time synchronized?

Human Eye: 10 – 25 images per second  
Clocks can be off by 40 ms – 100 ms

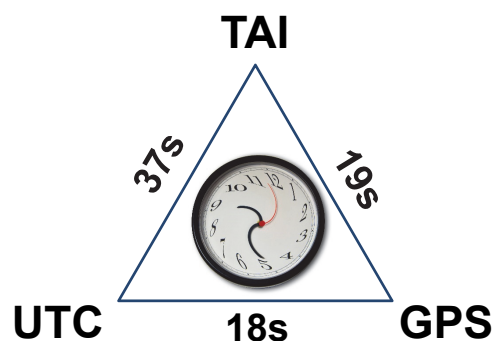
It depends!

© OMICRON

Page 3

OMICRON

## Time Systems



**TAI:** Average of 400 atomic clocks (reference)

**GPS:** TAI – 19 s (fixed)

**UTC:** TAI – 37s (variable)\*

\*Leap seconds can be added or removed twice a year.  
So far 37 leap seconds have been added.

OMICRON

## Time Performance Requirements in IEC 61850

IEC 61850-5:

Time Performance Class	Accuracy	Purpose
T1	$\pm 1$ ms	Time tagging of events
T2	$\pm 100$ $\mu$ s	Time tagging of zero crossings and of data for the distributed synchrocheck. Time tags to support point on wave switching
T3	$\pm 25$ $\mu$ s	Instrument transformer synchronization (Sampled Values)
T4	$\pm 4$ $\mu$ s	
T5	$\pm 1$ $\mu$ s	

Time Error	Phase Error @ 50 Hz	Phase Error @ 60 Hz
1 ms	18°	21.6°
100 $\mu$ s	1.8°	2.2°
55.5 $\mu$ s	1.0°	1.2°
46,3 $\mu$ s	0.8°	1.0°



## IEEE 1588 / PTP in a nutshell

- > It's the **P**recision **T**ime **P**rotocol (PTP)
- > The IEEE 1588 standard defines the **most accurate** method to **synchronize clocks** over computer networks
- > Defined for use in local area networks (LAN)
- > IEEE 1588 uses „**profiles**“ to define **default settings, methods** and **adaptations** for different industries
- > Two versions of the standard are in use
  - > IEEE 1588 – 2002 (v1)
  - > IEEE 1588 – 2008 (v2)



## IEC/IEEE 61850-9-3 in a nutshell

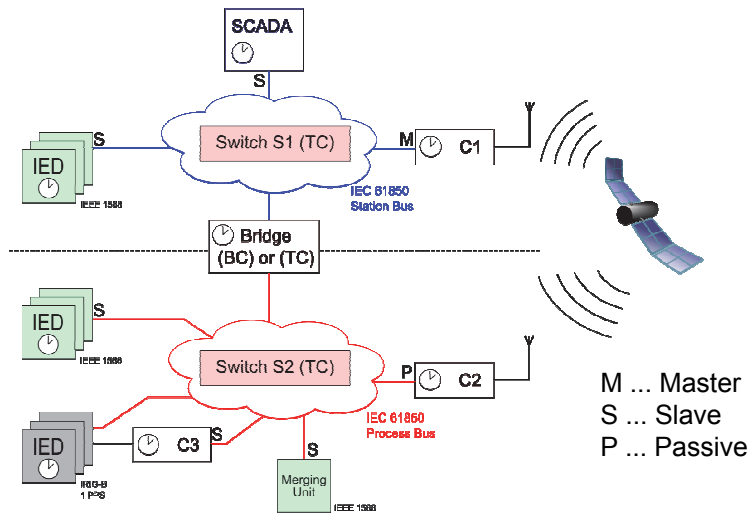
- > Since 2016 a dual logo standard (IEEE and IEC)
- > Is a **PTP profile** in accordance to IEEE 1588v2
- > Uses the **Peer to Peer** mechanism
- > Supports the standard **Best Master Clock Algorithm** (BMCA)
- > Uses Layer 2 (IEEE 802.3)
- > Default values are compatible with IEEE C37.238-2011
- > Defines specific behavior and accuracies for the electric power industry



## PTP Terminology

- > **Grandmaster Clock**
  - > a clock that can be a master of all other clocks
- > **Current Grandmaster**
  - > the clock that has taken over control and is the master of all clocks, all other grandmasters are passive
- > **Slave Clock**
  - > a clock that is locked to a grandmaster
- > **Transparent Clock**
  - > a PTP compliant Ethernet switch
- > **Boundary Clock**
  - > transfers time between two independent PTP networks

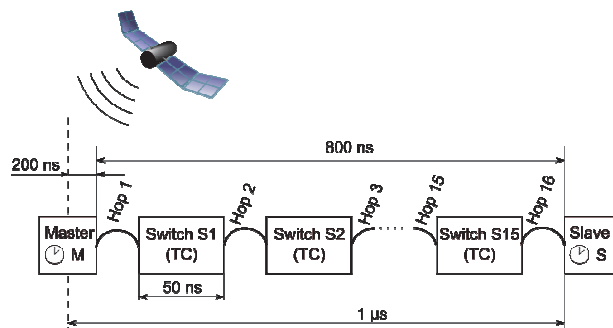
## Implementation Example



OMICRON

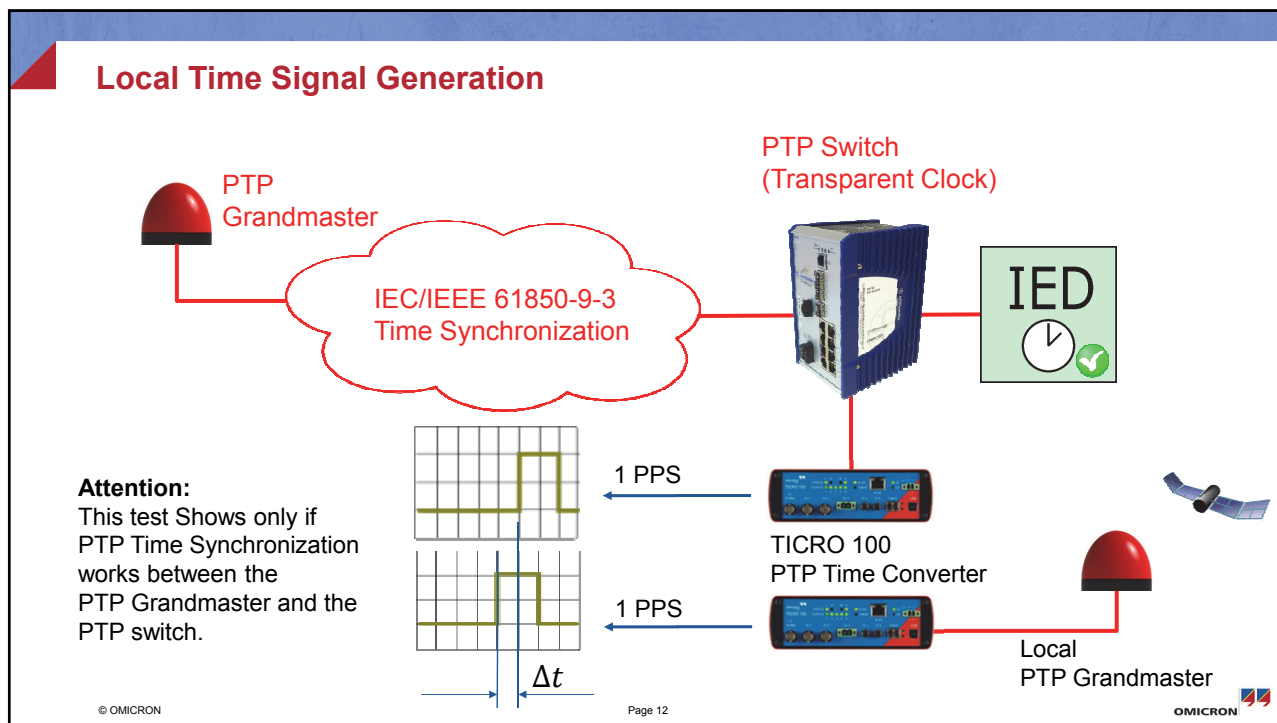
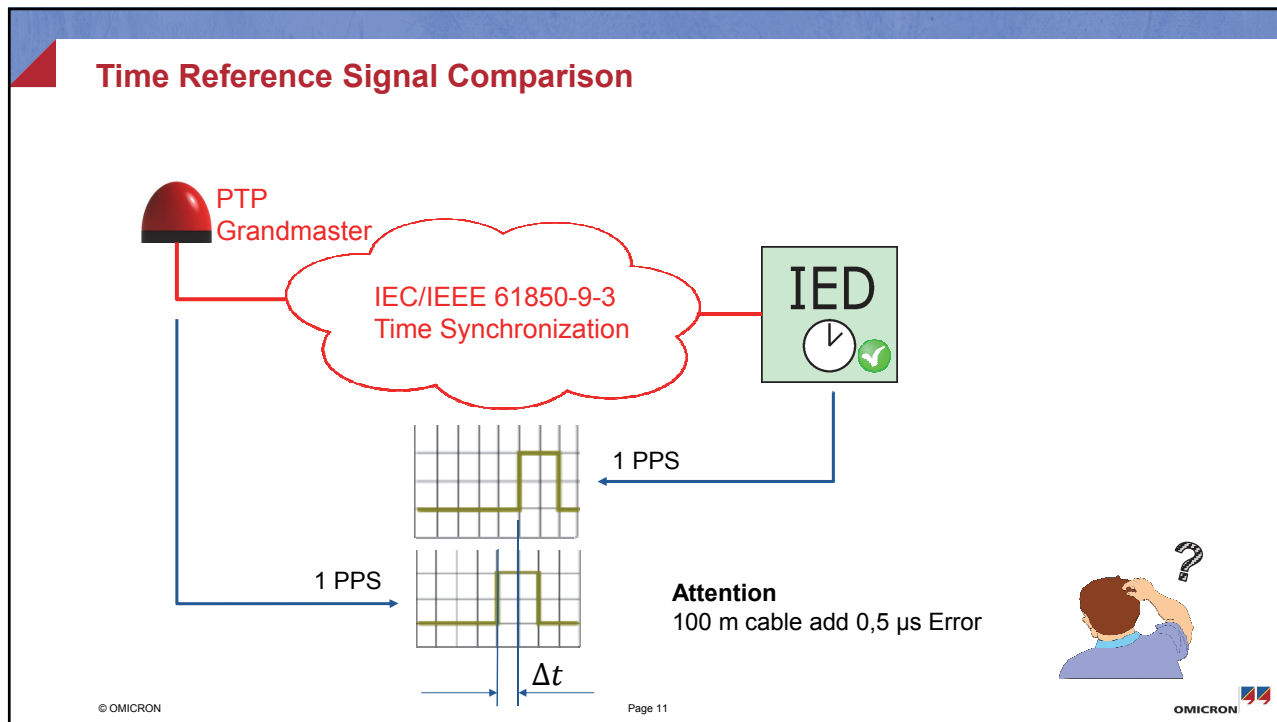
## IEC/IEEE 61850-9-3 accuracy parameters

- > Hold-over time for grandmaster clocks
  - > < 250 ns drift within 5 seconds  
(to ensure safe switch over for BMCA)
- > Steady State performance
  - > better 1  $\mu$ s after 15 TC's
  - > better 1  $\mu$ s after 3 BC's



Page: 10

OMICRON

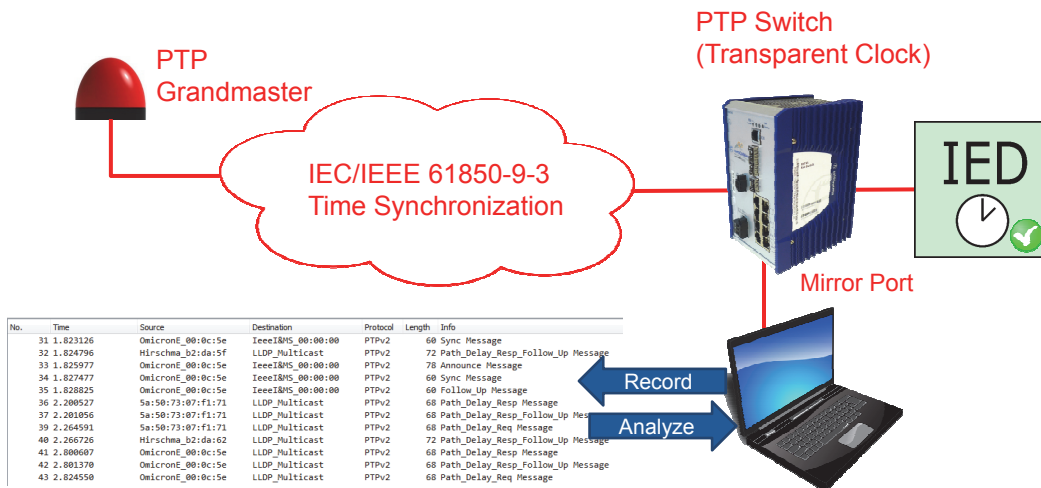


## Possible Information provided by a good PTP Client



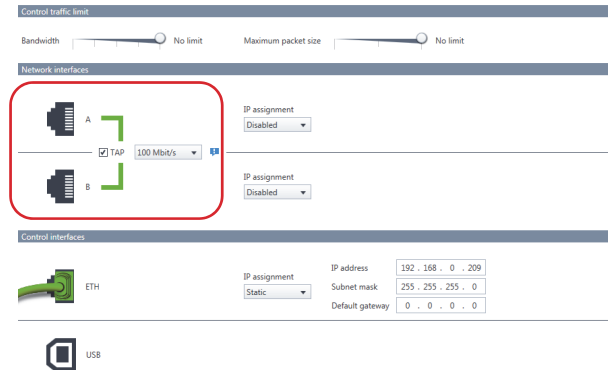
Port		Parent	
Port state:	Slave	Port identity:	1@20:b7:c0:ffe:00:0c:5e
Delay mechanism:	P2P	Grandmaster identity:	20:b7:c0:ffe:00:0c:5e
Sync interval:	1 s	Grandmaster clock class:	PRIMARY_REF_PTP (6)
Announce interval:	2 s	Grandmaster clock accuracy:	WITHIN_100_NS (0x21)
Announce receipt timeout:	3	Grandmaster clock variance:	18465
Minimum pdelay request interval:	1 s	Grandmaster priority 1:	128
Peer mean path delay:	63 ns	Grandmaster priority 2:	126
Delay asymmetry:	0 ns		
Profile ID:	00:0c:cd:00:01:00	Time	
Network protocol:	IEEE_802_3	UTC offset:	37 s
		UTC offset valid:	true
		Leap 59:	false
		Leap 61:	false
		Time traceable:	true
		Frequency traceable:	true
		PTP time scale:	true
		Time source:	GPS (0x20)
Current			
Steps removed:	1		
Offset from master:	28 ns		

## PTP Traffic Analysis

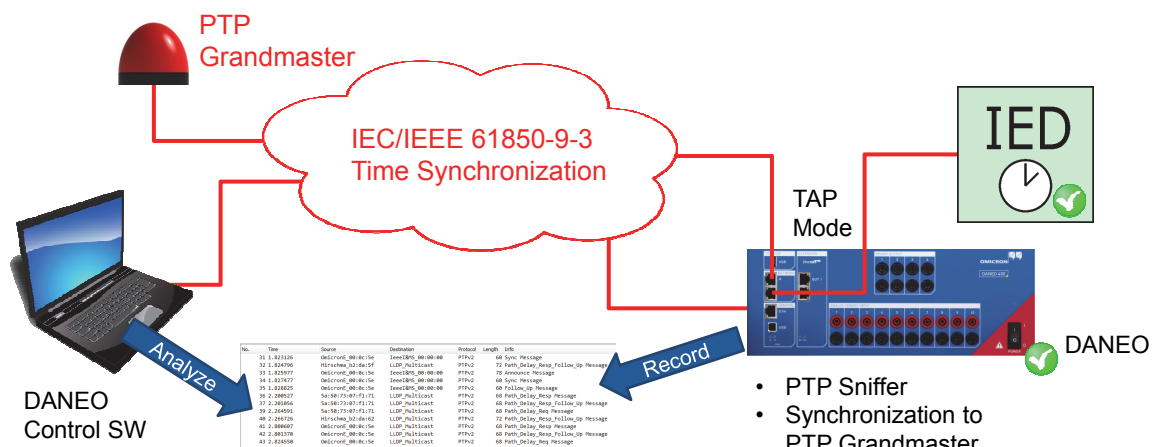


## TAP Mode

- > Can be used to look at PTP traffic without the need of an available port at a switch
- > Acts like a Ethernet cable for the outside world
- > Allows to record incoming packets at both ports



## PTP Traffic Analysis with DANE0

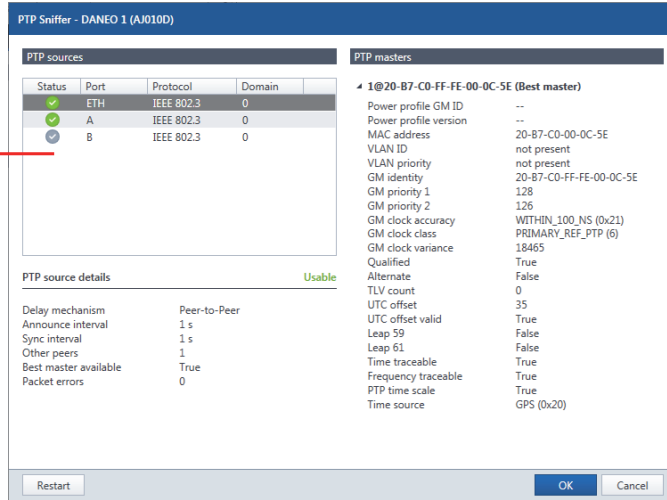
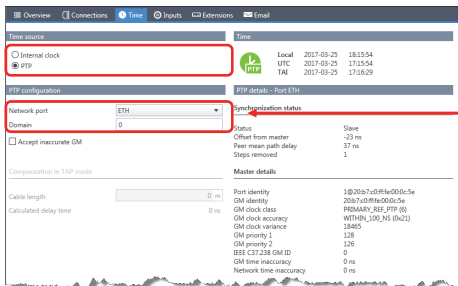


- PTP Sniffer
- Synchronization to PTP Grandmaster
- Trigger traffic recording on events (e.g. GOOSEs)

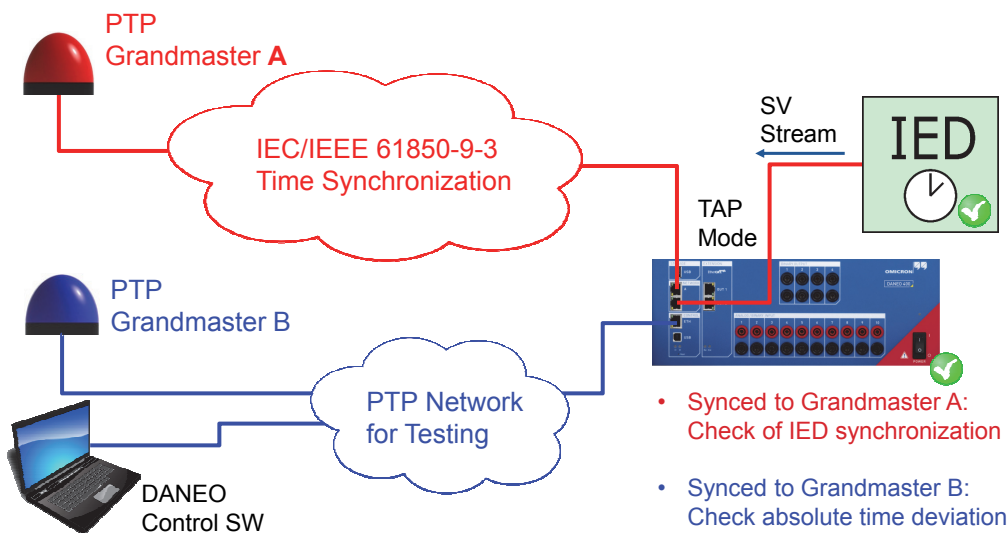


## PTP Sniffer in DANEO

- > All details of active PTP clocks in the network
- > Easy configuration of DANEO time synchronization
- > Synchronize DANEO to any port (including ports in tap mode)



## Sampled Value Stream arrival time



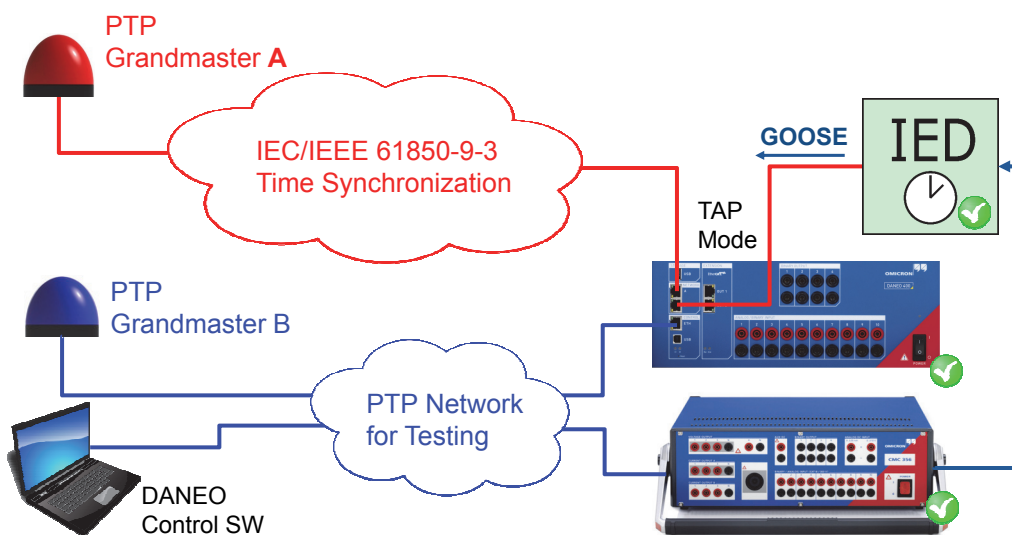
## SV stream synchronization

SV IEDxMUnn/LLN0\$SV\$MSVCBox			
Details			
Control block reference	IEDxMUnn/LLN0\$SV\$MSVCBox		
Destination MAC address	01-0C-CD-04-00-01		
Application ID	16385 (0x4001)		
SV ID	MuSiemens		
Sample rate	4000		
Sample mode	Samples per second		
noASDU	1		
DataSet reference	IEDxMUnn/LLN0\$PhsMeas		
VLAN ID	0		
VLAN priority	4		
Configuration revision	1		
Source MAC address	08-00-06-91-38-AC		
Simulation/Test	False		
Synchronization status	Synchronized (2)		
Number of DataSet entries	16		
Statistics			
	A	B	ETH
Receive time		2017-03-27 13:49:57.775	
Samples seen		16000	
Samples missed		0	
Sampling rate		4,000 kHz	
Last packet smpCnt=0		2017-03-27 13:49:57.001	
Clock drift (current)		-7.34 $\mu$ s	
Clock drift (since start)		-5.01 $\mu$ s	
Timed out		False	
Timed out count		0	
Packet interval:			
Minimum		223,84 $\mu$ s	
Maximum		277,37 $\mu$ s	
Average		250,00 $\mu$ s	
Packet delay:			
Minimum		515,49 $\mu$ s	
Maximum		556,25 $\mu$ s	
Average		527,35 $\mu$ s	

SV IEDxMUnn/LLN0\$SV\$MSVCBox			
Details			
Control block reference	IEDxMUnn/LLN0\$SV\$MSVCBox		
Destination MAC address	01-0C-CD-04-00-01		
Application ID	16385 (0x4001)		
SV ID	MuSiemens		
Sample rate	4000		
Sample mode	Samples per second		
noASDU	1		
DataSet reference	IEDxMUnn/LLN0\$PhsMeas		
VLAN ID	0		
VLAN priority	4		
Configuration revision	1		
Source MAC address	08-00-06-91-38-AC		
Simulation/Test	False		
Synchronization status	Not synchronized (0)		
Number of DataSet entries	16		
Statistics			
	A	B	ETH
Receive time		2017-03-27 12:13:52.597	
Samples seen		32000	
Samples missed		0	
Sampling rate		4,000 kHz	
Last packet smpCnt=0		2017-03-27 12:13:52.210	
Clock drift (current)		3,26 $\mu$ s	
Clock drift (since start)		7,54 $\mu$ s	
Timed out		False	
Timed out count		0	
Packet interval:			
Minimum		220,08 $\mu$ s	
Maximum		279,36 $\mu$ s	
Average		250,00 $\mu$ s	
Packet delay:			
Minimum		209,88 ms	
Maximum		209,92 ms	
Average		209,89 ms	

## Check arrival time of GOOSEs



## GOOSE packet delay measurement

G ISIO_AM174KBX/LLN05G0SGCB			
<b>Details</b>			
Control block reference	ISIO_AM174KBX/LLN05G0SGCB		
Destination MAC address	01-0C-CD-01-00-00		
Application ID	1 (0x0001)		
GOOSE ID	GoId		
DataSet reference	ISIO_AM174KBX/LLN05GooseDataSet1		
VLAN ID	0		
VLAN priority	4		
Needs commissioning	False		
Configuration revision	1		
Source MAC address	20-87-C0-00-3E-89		
Simulation/Test	False		
Entry time	2017-03-27 13:56:05.849		
Status number	63		
Sequence number	9		
Time to live	8192 ms		
Number of DataSet entries	16		
<b>Statistics</b>			
	A	B	ETH
Receive time			2017-03-27 13:56:09.938
Packet count			248
Status changes seen			38
Status changes missed			0
Retransmissions missed			0
Duplicates seen			0
Time to live expired			False
Time to live expired count			0
Packet delay:			
Minimum			990.79 µs
Maximum			1.66 ms
Average			1.32 ms

G ISIO_AM174KBX/LLN05G0SGCB			
<b>Details</b>			
Control block reference	ISIO_AM174KBX/LLN05G0SGCB		
Destination MAC address	01-0C-CD-01-00-00		
Application ID	1 (0x0001)		
GOOSE ID	GoId		
DataSet reference	ISIO_AM174KBX/LLN05GooseDataSet1		
VLAN ID	0		
VLAN priority	4		
Needs commissioning	False		
Configuration revision	1		
Source MAC address	20-87-C0-00-3E-89		
Simulation/Test	False		
Entry time	2017-03-27 13:54:01.768		
Status number	7		
Sequence number	11		
Time to live	8192 ms		
Number of DataSet entries	16		
<b>Statistics</b>			
	A	B	ETH
Receive time			2017-03-27 13:54:15.761
Packet count			49
Status changes seen			6
Status changes missed			0
Retransmissions missed			0
Duplicates seen			0
Time to live expired			False
Time to live expired count			0
Packet delay:			
Minimum			1.71 s
Maximum			1.71 s
Average			1.71 s

## PTP supervision with DANEO

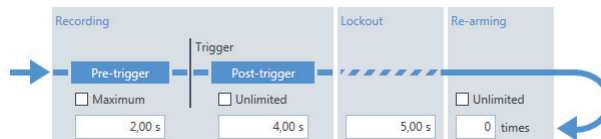
> Use PTP events as triggers

- PTP
- Synchronization lost
- Grandmaster accuracy changed
- Synchronization established
- Grandmaster ID changed
- UTC offset updated

> Start recording (e.g. PCAP)

- > Pre & post trigger
- > Re-arming after Lockout (multiple recordings)

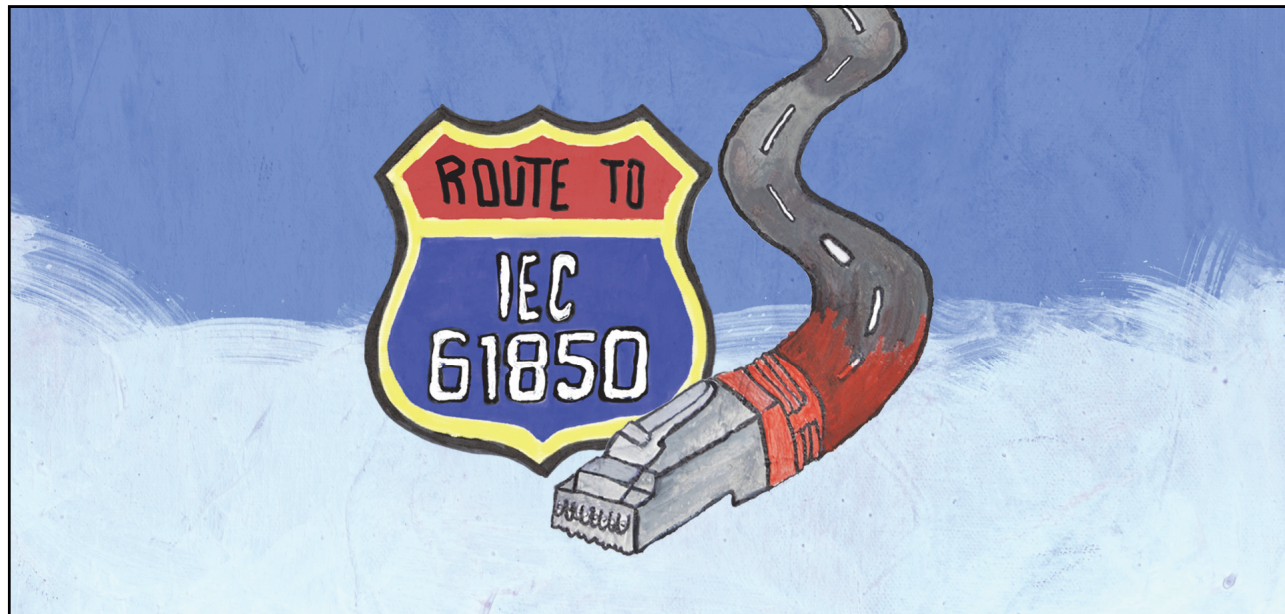
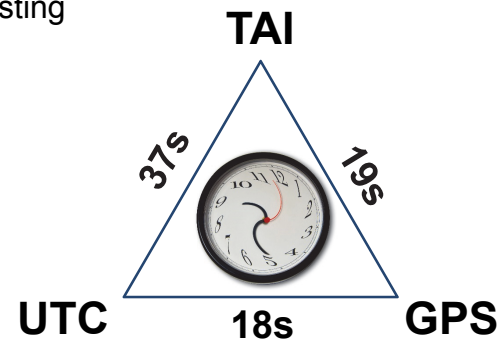
> Get Email notifications



## Summary

- > Sync Indications alone are not enough - good devices give you more
- > There is a lot of information available in the PTP traffic
- > Looking at GOOSEs and SV streams helps
- > Having an independent time reference for testing is beneficial
- > It's always good to have 1PPS outputs

**Never forget ...  
there is more than one time scale**



**Thanks a lot for your attention!**