IEC 61850-9-3
Will simplicity supersede complexity?

Bernhard Baumgartner, Christian Riesch, Wolfgang Schenk
OMICRON electronics GmbH
bernhard.baumgartner@omicron-lab.com
Austria

Abstract

With the release of the IEC 61850-9-3 “Power Utility Profile” in the middle of 2015 the precision time protocol (PTP) defined in IEEE 1588-2008 became officially an integral part of the 61850 world. But what does this mean for the planning of future substation environments? Will 9-3 replace the earlier introduced “Power Profile” defined in IEC C37.238-2011? Or will we face a battle of profiles? These and several other questions in relation to IEC 68150-9-3 are addressed in this paper. Based on the current implementation situation and the findings from the IEC 61850 interoperability plugfest 2015 the paper explores the differences and commonalities of the two PTP profiles for power applications and their interoperability.

A short history of time synchronization

In nearly all areas of our daily life we trust in the correctness of time. We agree to meet at a certain time and we expect that everybody will show up on time. This initial expectation is based on several assumptions. First of all we assume that all meeting participants have the intention to show up on time. Further on, we assume that everybody has access to a sufficiently accurate watch. And finally, we assume that the watches of all participants are synchronized towards the same time reference. In principle all these assumptions will hold, but there are many nice things such time zones and daylight saving time that make things a little bit more complicated.

Time synchronization is not a problem of modern times. For centuries it was difficult to determine the exact longitude at which ships are located due to the fact that no sufficiently accurate portable watches were available. This problem was solved by Mr. John Harrison in 1759. His famous “Sea Watch” - officially known as H4 - was first tested on a trip between the UK and Jamaica and back. During the 81 day and 5 hour trip the clock accumulated a deviation of only five seconds against its time reference, the Greenwich Mean Time (GMT). So let’s start our journey into modern time synchronization with a look at the different time scales that are valid nowadays.

UTC, TAI and the GPS time scale

As mentioned in the introduction, one of the first internationally used time scales was the Greenwich Mean Time (GMT). In 1884 the local mean solar time at the Royal Observatory in Greenwich near London was chosen as the international time reference, defining the universal day. This decision was supported by the fact that in two thirds of the nautical maps the Greenwich Meridian was used as their prime meridian. [1] In 1928 the term Universal time (UT) was introduced referring to the astronomical GMT time with the day starting at midnight. The UT was at that time still strictly linked to the rotation of the earth. [2] Starting from 1961 the Bureau International de l’Heure began coordinating UT internationally. This time scale is nowadays simply known as UTC (unofficially: Universal Time Coordinated).

The invention of the caesium atomic clock in 1955 laid the foundation for the definition of the SI second. But it took until 1967 until the SI second was officially linked to the caesium clock and defined as the duration of 9192631770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the caesium 133 isotope.[3] The SI second is independent from the rotation of the earth and equals practically the ephemeris second that had been provisionally used for atomic time since 1958 (officially named TAI[1] in 1971). It was soon detected that having two different second lengths, namely the UT second linked to the earth rotation and the SI second linked to the

[1] Temps Atomique International

caesium atomic clock is a bad idea. So it was decided to adopt the SI second for UTC as well. The final implementation of the SI second for UTC took place on 1 January 1972 at 00:00:00 UTC defining an offset of exactly 10 seconds to TAI. Due to the adoption of the SI second UTC was no longer linked to the rotation of earth. The rotation of earth is not constant and therefore UTC drifts away from the solar time at Greenwich (UT1). To ensure that UTC stays within ± 0.9 s of UT1 it was decided to insert leap seconds[2]. From 1972 until the time this paper was written a total of 26 leap seconds were inserted resulting in a total offset of 36s between TAI and UTC. The frequent insertion of leap seconds is internationally heavily disputed. Critics state that leap seconds can cause troubles in computer systems of all kind. The insertion of a leap hour in the year 2600 leap would avoid the frequent insertion of leap seconds and would be more effective. A decision on the future use of leap seconds was planned first for 2012, then shifted to 2015 and then again shifted to 2023.[5]

One might think that with TAI and UTC all time scale needs are covered. But interestingly new time scales are introduced quite frequently. The GPS time scale (GPST) for example was started on 6 January 1980 0:00:00 UTC. At that date the offset between UTC and TAI was 19 seconds. The GPST is a linear time scale not taking into consideration leap seconds. Therefore the offset between GPST and TAI will remain constant. [6]

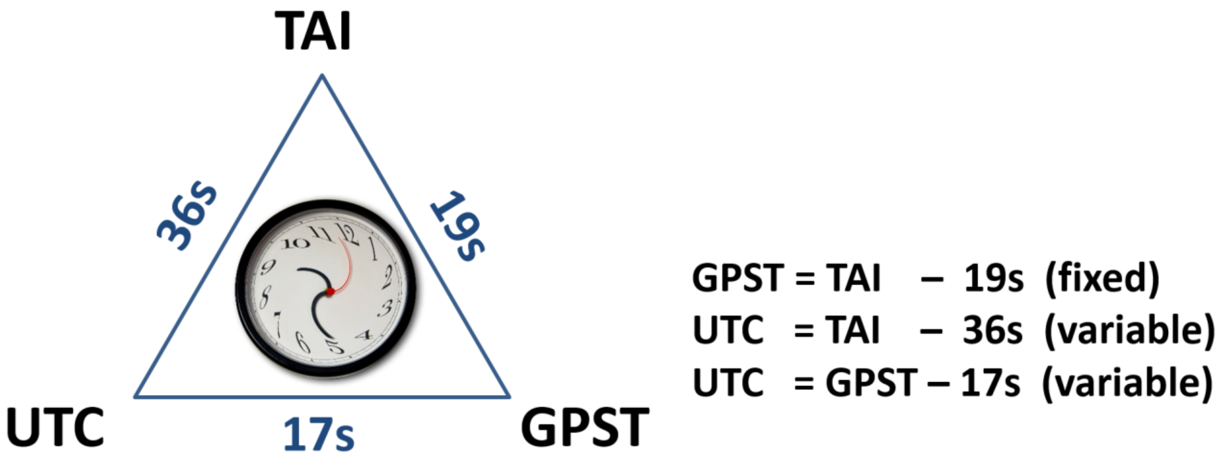

Figure 1 – Relationship between TAI, UTS and GPST at the time of writing this paper

Figure 1 summarizes the relationship between the discussed time scales. While the offset between GPST and TAI is fixed the offset between UTC and the two other time scales changes with the insertion of leap seconds. The offsets shown in Figure 1 are valid from 30. June 2015 until the insertion of the next leap second somewhere in the future.

To ensure that measurement data collected by different devices, at different locations and possibly in different time zones can be used for protection, automation and control it is essential that all data can be traced back easily to the same time scale. Thus, it is strongly recommended to stick to a continuous time scale like TAI.

[2] Leap seconds can be positive or negative. The insertion of a negative leap second reduces the offset between TAI and UTC.

Time Synchronization requirements in a smart substation

Before discussing time synchronization in accordance to IEC 61850-9-3 it is helpful to understand what technical and regulatory requirements apply to time synchronized measurements and time stamping of data in the modern power grid.[3]

With the adoption of the NERC[4] Standard PRC-018-1 [8] in 2006 it is now a legal obligation that all recorded data in North America must have an accuracy of 2 ms or better in relation to UTC. Nowadays, most measurement and control data in the power grid must have an absolute accuracy of approximately 1 ms: [9]

- SCADA[5] Data
- Data from Event and Disturbance Recorders
- Time Stamped Data from IEDs
- Lightning Strike Correlation

A time accuracy of 1 ms is relatively easy to reach, but some current and emerging future measurement applications require a much higher accuracy. The applications mentioned below, for example, require an absolute accuracy of 1 µs or better: [9]

- Sampled Values
- Synchrophasor[6] measurements
- Travelling Wave Fault Location

In order to time synchronize all devices involved in the processes and measurements mentioned above, usually GPS disciplined time references, commonly called substation clocks, are used.

In the IEC 61850-5 the time accuracy requirements for time tagging of events and time synchronized measurements are summarized in five time performance classes which range from 1 ms to 1 µs and are shown in Table 1.[10]

Time Performance Class	Accuracy	Purpose
T1	± 1 ms	Time tagging of events
T2	± 100 µs	Time tagging of zero crossings and of data for the distributed synchrocheck. Time tags to support point on wave switching
T3	± 25 µs	Time performance classes for instrument transformer synchronization
T4	± 4 µs	
T5	± 1 µs	

Table 1 - Time performance classes according to IEC 61850-5

To ensure that all time synchronized IEDs operate within the accuracy defined by the applicable time performance class, time reference signals are distributed throughout the substation. This can happen via a separate time synchronisation network or via the station communication network. In addition, some IEDs can be equipped with their own GPS clocks if the chosen time synchronization method does not meet the accuracy requirements of the respective IEDs. (See Figure 2 for details).

[3] The following section is an extract of a paper previously published by the authors [7]
[4] North American Electric Reliability Cooperation
[5] Supervisory Control & Data Acquisition
[6] Synchronized phasor measurements of sinusoidal quantities synchronized in time and expressed as phasors.

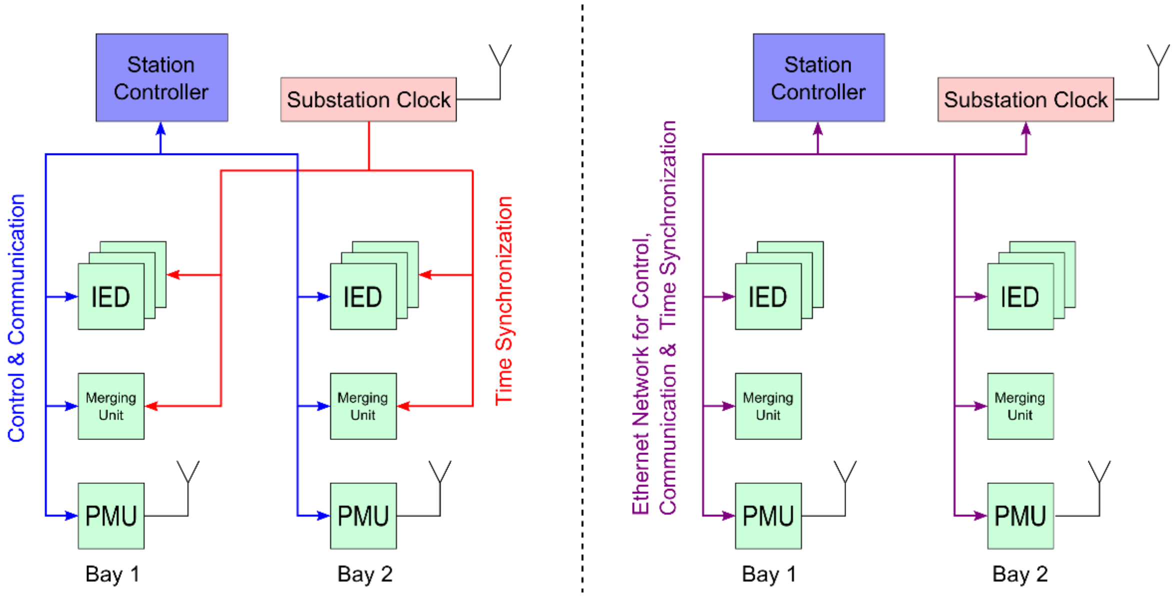

Figure 2 - Time distribution infrastructures in substations

The implementation of IEC 61850 drastically reduces the need of copper connections in-between IEDs and between the IEDs and the station controller. Hence, it is obvious that also a time synchronization method is to be preferred that uses the existing IEC 61850 network infrastructure and does not need separate wiring. Further on it makes sense to pick a future proof method that is accurate enough to allow applications in all time performance classes outlined in Table 1.

Time Synchronization Method	Typical Accuracy	Distribution	Ambiguity
IRIG-B	10 µs - 1 ms	Separate wiring	1 year (100 years with extension)[7]
DCF 77 (digital)	1 µs – 100 ms	Separate wiring	100 years
1PPS	< 1 µs	Separate wiring	1 second
Serial ASCII	1 ms	Separate wiring	None
NTP	1 ms - 10 ms	Ethernet (IEC 61850 Bus)	None
PTP (IEEE 1588)	< 1 µs	Ethernet (IEC 61850 Bus)	None

Table 2 – Comparison of different time synchronization methods

As shown in Table 2 only the precision time protocol (PTP) in accordance to IEEE 1588 fulfills the accuracy and distribution requirements outlined above. More and detailed information on the other time synchronization methods summarized in Table 2 can be found in [9].

[7] The IEEE 1344 Extension introduced a two digit information for the year (2000 – 2099). In the meantime IEEE 1344 has been replaced with IEEE C37.118-2005.

A short introduction to PTP[8]

PTP was originally defined in 2002. The IEEE 1588-2002 introduced a network based time synchronization method for applications in local area networks that require a higher accuracy than the one provided by the Network Time Protocol (NTP). In 2008 a revised version was released. The new version IEEE 1588-2008, also known as PTP Version 2 or PTPv2, introduced several novelties that simplified the practical application of PTP. [13] Unfortunately PTPv2 is not backwards compatible to IEEE 1588-2002 which definitely delayed the roll out of PTP.

PTP utilizes a continuous timescale based on TAI. The PTP epoch[9] is 1 January 1970 00:00:00 TAI. Time stamps are defined as a combination of a 48 bit integer number (for seconds) and a 32 bit integer number (for nanoseconds). With these numbers all points in time for the next 8.9 million years can be time stamped with a nanosecond resolution.[10]

PTP is using a master slave topology in which all slave clocks are synchronized to a single clock, the grandmaster of the system. The grandmaster clock is typically synchronized to a primary time reference (e.g. a GPS receiver). The synchronization of the slaves happens via the exchange of data packets as shown in Figure 3. To ensure that the correct time offset Δt_{ms} between the master and the slave can be determined it is necessary that the propagation delay through the network is equal for data packets in both directions. To achieve this goal, PTP-capable Ethernet switches, so called transparent clocks, are required. Transparent clocks timestamp PTP packets at ingress and egress. From these time stamps the residence time of the packet inside the switch is calculated and added into a field of the respective data packet or a follow up message. [9].

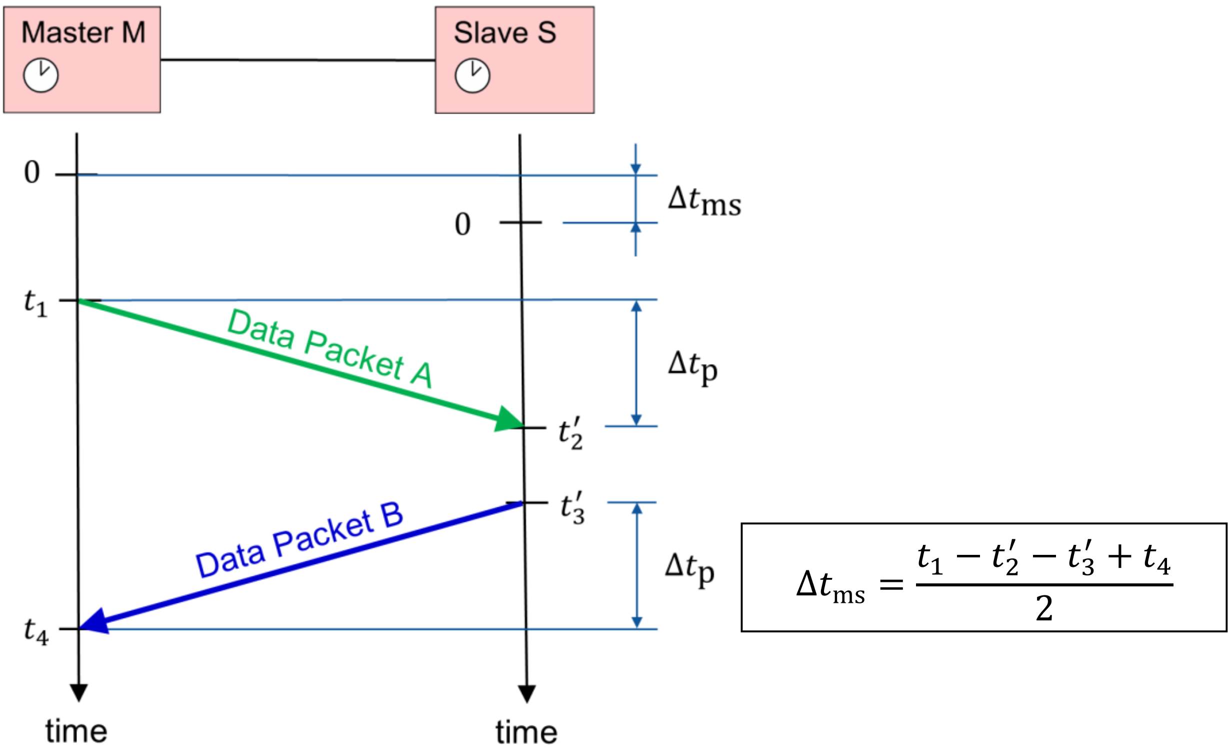

Figure 3 – Determination of the time offset Δt_{ms} between master and slave

Based on the principle shown above IEEE 1588-2008 offers two time delay measurement mechanisms: The end-to-end (E2E) and the peer-to-peer (P2P) mechanism. In E2E configuration the delay measurement takes place separately between the master and each connected slave. This results in

[8] This section is a shortened excerpt from a paper which has been published previously by the authors. For more details on the described PTP characteristics please refer to [9].
[9] The epoch is the origin of the timescale.

increased traffic towards the master clock since the master needs to communicate with each slave individually as shown in Figure 4.

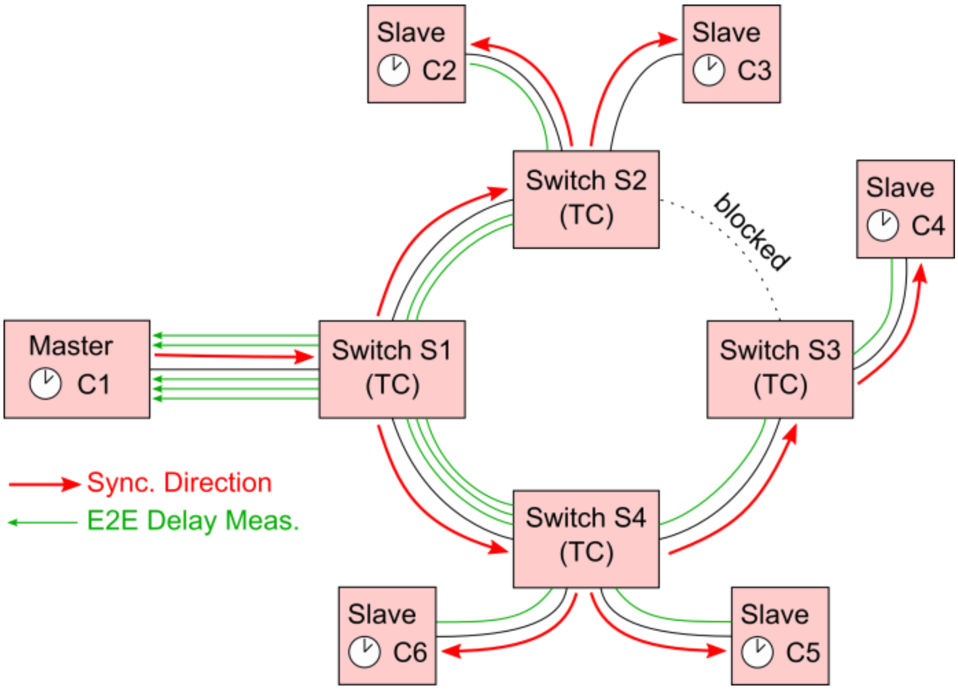

Figure 4 – E2E in a ring topology

In a P2P configuration the master must only communicate with the transparent clock it is connected to. All transparent clocks in the network then measure the link delays to neighboring transparent clocks and connected slave clocks. The delay measurement is also performed for links which are blocked by a redundancy protocol. (See Figure 5) This allows a quick reconfiguration since the delay for the blocked link is readily available in case it has to be included into the synchronization path. [14]

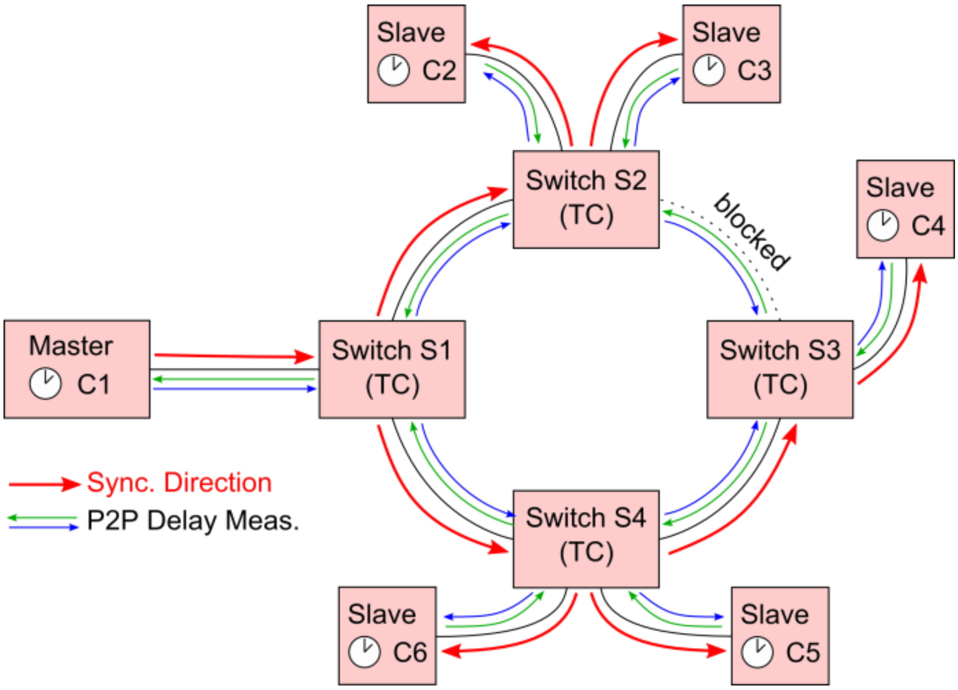

Figure 5 – P2P in a ring topology

All clocks in a network including the transparent clocks and grandmaster clocks need to use the same delay measurement mechanism to ensure proper time synchronization.

One of the key features of PTP is the Best Master Clock Algorithm (BMCA). It ensures that only one master clock is the grandmaster of the entire network, while all other master clocks in the network remain in passive operation. When a network is started up all grandmaster clocks send out announce messages. In the announce message a master clock informs all other master clocks about its priority, accuracy, clock class etc. The BMCA performs an ordered comparison of these parameters. [13] As a result only the best master clock becomes the grandmaster of the network while all other master clocks remain passive. If a better master clock is connected to the network or if the existing grandmaster is malfunctioning the new best master clock is automatically determined and all slave clocks lock seamlessly to the new grandmaster as shown in Figure 6.

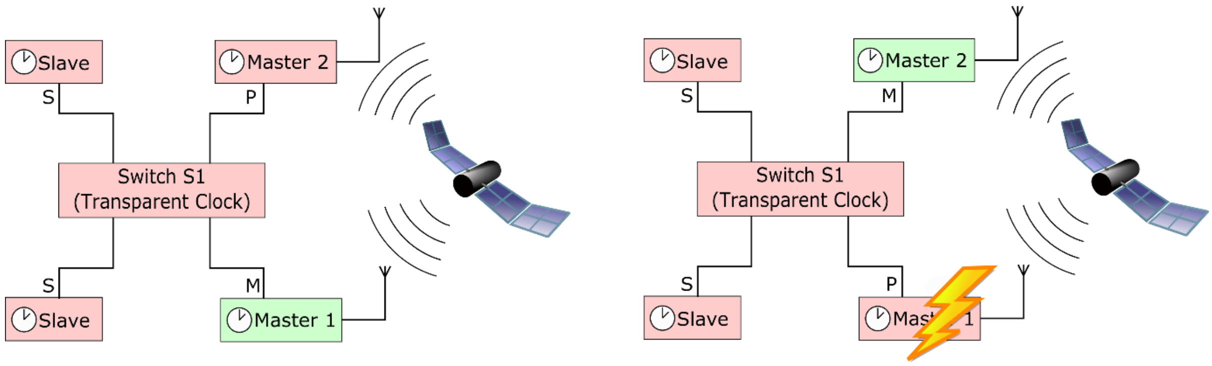

Figure 6 – Concept of BMCA switch over

IEEE 1588-2008 is a very comprehensive standard with close to 290 pages. It offers many different configuration parameters and possibilities. To ensure interoperability and optimum application within a certain industry PTPv2 introduced the possibility to define PTP profiles. A PTP profiles summarizes which default settings and parameters are to be used for a certain application. Further on it allows to define industry specific extensions of the standard as well as specific performance requirements. This sets the scene for IEC 61850-9-3.

IEC 61850-9-3

With the introduction of the IEC PAS 61850-9-3:2015 “Communication networks and systems for power utility automation - Part 9-3: Precision time protocol profile for power utility automation“[10] on 12 June 2015 PTP finally became an official part of IEC 61850. The power utility profile 9-3 was released as Publicly Available Specification (PAS). According to IEC a PAS is a publication responding to an urgent market need.[15] On the first glance one might think that this is a little bit astonishing due to the fact that with the IEEE C37.238-2011 “IEEE Standard Profile for Use of IEEE 1588 Precision Time Protocol in Power System Applications”[11] a PTP profile for the power industry has already been available for a while. But before we further investigate this matter let’s have a closer look at 9-3.

Definitions and parameters of IEC 61850-9-3

The 9-3 describes a PTP profile for power utility automation which allows to comply with the highest time performance classes defined in IEC 61850-5. It utilizes

- Layer 2 communication (IEEE 802.3),
- the peer-to-peer delay measurement mechanism,
- multicast communication,

[10] In the following text the abbreviations “9-3” or “power utility profile” are used for IEC PAS 61850-9-3

[11] In the following text the abbreviation “power profile” is used for IEE C37.238-2011

- and the default best master clock algorithm.[16]

To be compliant with IEC 61850-9-3 each device needs to support at least one of three management mechanisms:

- SNMP MIB in accordance to IEC 62439-3:2015
- Management objects defined in IEC 61850-90-4:2013
- Manufacturer specific implementation to address all configurable values stated in IEEE 1588-2008 clause 15.1.1.

It further on defines default values for PTP attributes as shown in Table 3. The PTP attributes have been chosen in a way that clocks compliant to the default peer-to-peer profile defined in J.4.2. of IEEE 1588-2008 can be configured to lock to an IEC 61850-9-3 grandmaster clock.

PTP Attribute	Default value
Domain number (defaultDS.domainnumber)	0
Log announce interval (portDS.logAnnounceInterval)	0
Log sync interval (portDS.logSyncInterval)	0
Log min delay request interval (portDS.logMinPdelay_ReqInterval)	0
Announce receipt timeout (portDS.announceReceiptTimeout)	3

Table 3 - Most important PTP attributes for the power utility profile[12]

Clock types defined in IEC 61850-9-3

9-3 defines the clock-types ordinary clock, transparent clock and boundary clock[13] in accordance with IEEE 1588-2008. But while an ordinary clock is referred to as either a grandmaster clock or a slave clock in IEEE 1588-2008 the 9-3 mentions the following three ordinary clock types:

- **Slave-only clock:**
  The port(s) of a slave-only clock are always in the slave state. It will lock itself to the grandmaster of the network. In case that no grandmaster is present it will remain in the slave state and never announce itself as a grandmaster.

- **Grandmaster-only clock:**
  A grandmaster-only clock announces itself as a grandmaster. If it is the best clock in the network it will become the grandmaster. Otherwise it will switch its ports to passive. A grandmaster-only clock will lock only to its primary time reference (e.g. GPS) but never to another grandmaster in the network.

- **Grandmaster-capable clock:**
  A grandmaster-capable clock can switch its ports either to the master or the slave state. Further on a grandmaster-capable clock does not necessarily require a primary time reference. This introduces an interesting alternative in case that all grandmaster-only clocks in a network are malfunctioning or are switching to hold-over[14]. In such a case a grandmaster-capable clock equipped with an accurate internal oscillator can become grandmaster of the network. Figure 7 illustrates this approach in detail.

[12] Table 3 shows a summary of the most important PTP attributes defined in Table 1 of 9-3 [16]

[13] A boundary clock is a clock that has ports in two or more domains. The boundary clock synchronizes to a grandmaster in one domain and acts as a grandmaster in all other domains. It is used to time synchronize two or more separate networks infrastructures to one grandmaster without the need of bridging data packets between the networks.

[14] Hold-over means that a clock runs on its internal oscillator.

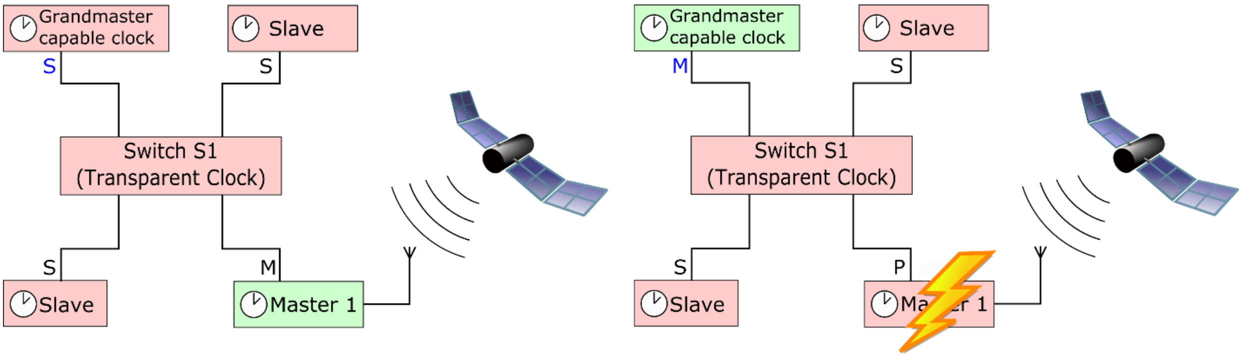

Figure 7 – Concept of grandmaster-capable clock

On the left hand side of Figure 7 a PTP network in regular operation is shown. The master clock 1 is locked to GPS and is grandmaster of the network. All other clocks including the grandmaster capable clock in the top left corner are in the slave state and are locked to master 1. On the right hand side of Figure 7 master 1 has a malfunction and can no longer act as a grandmaster. In this example the grandmaster capable clock has a more stable internal oscillator than master 1. Since it has been locked master 1 previously it also has an accurate time. Therefore it can announce itself as master and ensure that the network stays in sync. As soon as master 1 is again locked to GPS the BMCA will ensure that master 1 will become grandmaster again.

Time inaccuracy defined in IEC 61850-9-3

To be compliant with IEC 61850-9-3 all involved clocks must not exceed the maximum time inaccuracy defined in the standard. The overall target is to achieve a network time inaccuracy of less than 1µs in comparison to the primary time reference after 15 transparent clocks or 3 boundary clocks. Table 4 summarizes the requirement specifications which have to be fulfilled by the individual clocks in steady state[15]. Figure 8 visualizes these requirement for a chain of transparent clocks. [16]

Clock	Maximum time inaccuracy inserted
Grandmaster Clock	250 ns (in comparison to its time reference
Transparent Clock	50 ns (between ingress and egress)
Boundary Clock	200 ns (between master and slave port)

Table 4 – Maximum time inaccuracies

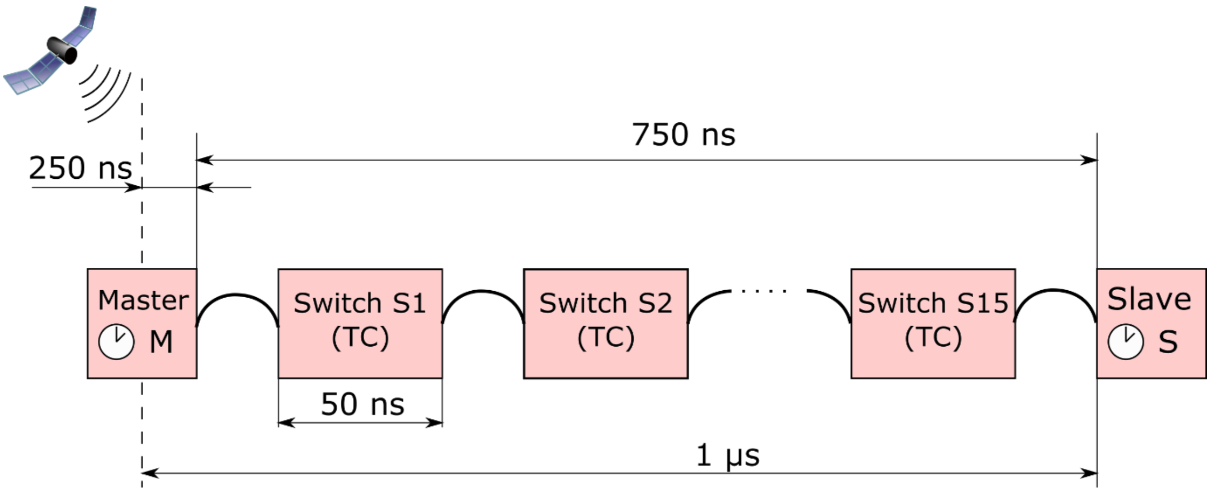

Figure 8 – Time inaccuracy for a chain of transparent clocks

[15] Steady state is defined as 30 s after a single master starts to send sync messages and 16 s after the change of the master (BMCA switch over)[16]

Hold over of grandmaster clocks and boundary clocks
To ensure that networks stay synchronized in cases of a grandmaster switch-over all grandmaster and boundary clocks need to remain within 250 ns of its time reference for at least 5 seconds. In the case that a grandmaster clock loses its time reference it changes its clock class as shown in Table 5.

Clock Class	Specification
6	Grandmaster clock is locked to its time reference signal and within 250 ns to this time reference signal.
7	Grandmaster clock is in holdover and within 250 ns in comparison to its previous time reference signal
52	Grandmaster clock is in hold over its time inaccuracy is bigger than 250 ns but smaller than 1 µs in comparison to its previous time reference signal
187	Grandmaster clock is in hold over its time inaccuracy is exceeds 1µs in comparison to its previous time reference signal

Table 5 – Clock Class switching in accordance to IEC 61850-9-3

After recovering synchronization to its time reference and being in steady state the grandmaster switches back to clock class 6. The clock class switching outlined above modifies the clock classes of IEEE 1588-2008 to reflect the timing requirements of IEC 61850-9-3.

IEC 61850-9-3 in comparison to IEEE C37.238-2011
The Power Utility Profile is not the first PTP profile that has been defined for the electric power industry. Already in 2011 the so called "Power Profile" was released by the IEEE.[17] In this section the communalities and differences between the two standards are evaluated.

	IEEE C37.238-2011	IEC 61850-9-3
Delay measurement mechanism	Peer–to–Peer (P2P)	
PTP Attributes	exactly the same PTP attributes are used	
Communication Layer	Layer 2 (IEEE 802.3)	
Communication method	Multicast communication	
Best Master Clock Algorithm	Clocks not using the IEEE C37.238-2011 mandatory TLV are excluded from the BMCA	Default BMCA is used
Major extensions[16] in relation to IEEE 1588-2008	• Mandatory profile specific TLV • Mandatory SNMP-MIB for Grandmaster clocks • Mandatory use of VLAN	• Modified clock class switching in case of hold over and recovery

Table 6 – Communalities and differences of IEEE C37.238 and IEC 61850-9-3

On the first glance one might think that there are so many communalities between the standards are available that the release of IEC 61850-9-3 might have been unnecessary. However, interoperability tests executed throughout the past years showed that especially the requirement for the mandatory use of VLANs defined in IEEE C37.238-2011 caused interoperability problems in praxis. During several tests the authors have been involved in, the VLAN functionality caused severe problems and had to be disabled to allow proper functioning of networks consisting of components provided from different vendors. Further on the exclusion of equipment that does not use the profile specific IEEE C37.238-TLV

[16] Performance requirements like clock inaccuracies or hold-over times etc. are not taking into consideration in this table since they are not changing the PTP behavior directly.

from the BMCA can result in unexpected and unwanted behaviour as it will be described in the following section of this paper.

Interoperability plugfest results

IEC 61850-9-3 testing

Only 3 months after the release of IEC PAS 61850-9-3 interoperability tests were performed at the 2015 IEC 61850 Interoperability plugfest 2015 (IOP) in Brussels. In total 10 companies participated in this first PTP interoperability tests ever performed at an IOP. The equipment provided by the participants covered all clock types described in the 9-3. In more than 15 test and use cases the interoperability of the equipment was assessed. [18]

Besides general synchronisation tests a key focus was laid on the time inaccuracies introduced by the devices under test (DUT). The performed tests showed that the implementation of IEC 61850-9-3 resulted in much lower time inaccuracies than defined in the standard. A chain consisting of one grandmaster and 6 switches in series inserted a time inaccuracy significantly smaller than the allowed inaccuracy of 550 ns[17].

To ensure that all performed tests reflect “real-life” use cases different test networks were built depending on the parameter or functionality to be tested. Figure 9 for example shows a test setup for the testing of the correct BMCA handling. Due to the fact that a GPS simulator was used during all tests it was possible to perform all the tests indoor without the need of running any antenna cables outside the meeting room. Further on it was possible to test the insertion of positive and negative leap seconds.

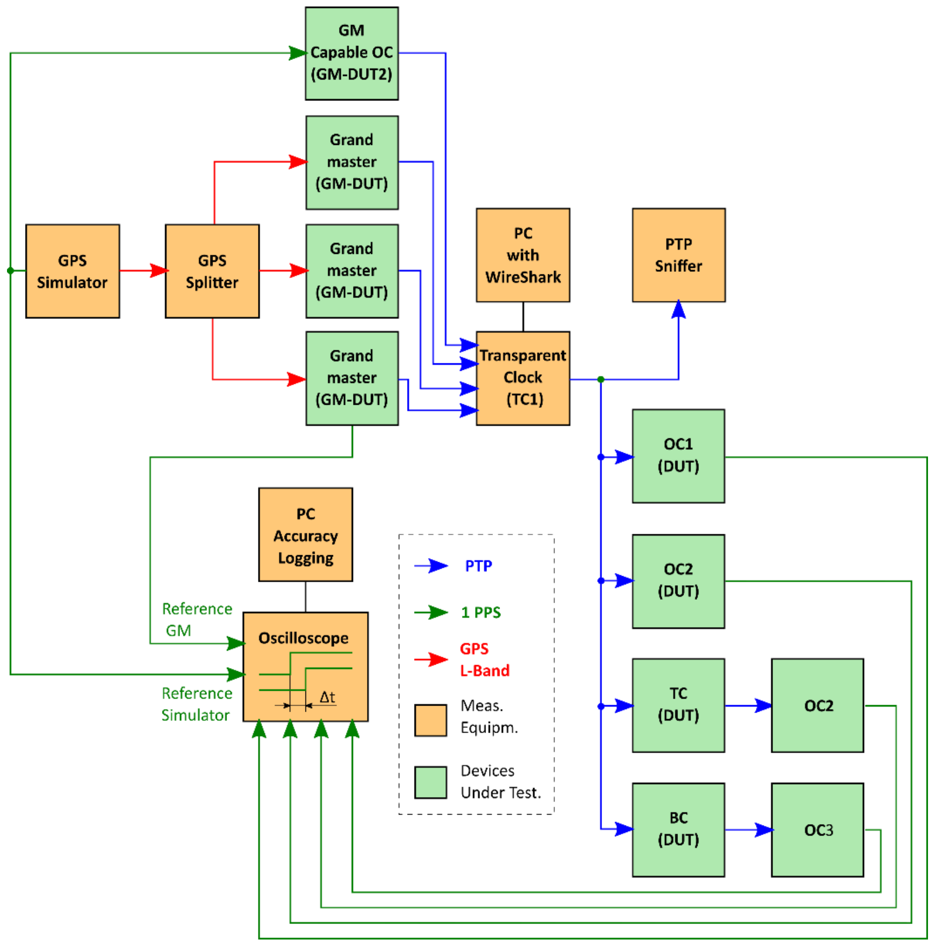

Figure 9 – Example for a test setup used during the IOP 2015

[17] 250ns (GM) + 6 * 50 ns (TC) = 550 ns (total)

Despite the short availability of the final standard only minor interoperability issues popped up during the IOP. Most of the causes for these issues were directly fixed during the IOP so that in the end no error report had to be handed in.

Interoperability test of IEC 61850-9-3 and IEEE C37.238

During the IOP 2015 also an interoperability test between the two profiles was performed. To allow synchronisation of IEC 61850-9-3 clocks the VLAN stripping was activated for the transparent clock used in the setup. The tests started with a simple test involving an IEEE C37.238 grandmaster and two slave clocks one of each profile as shown in Figure 10.

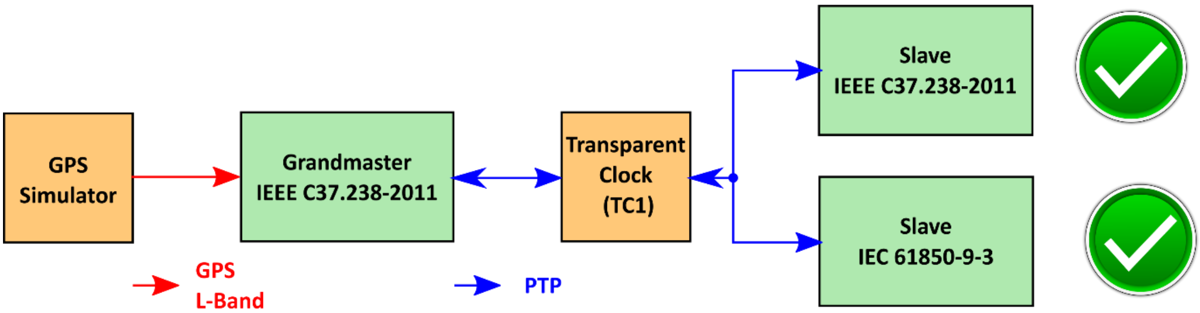

Figure 10 – Single IEEE C37-238-2011 grandmaster

Due to the fact that the VLANs where stripped and that the IEEE 37.238 TLV delivered by the grandmaster was ignored by the IEC 61850-9-3 slave both slave clocks did lock to the grandmaster. A quick test showed that both clocks were within an accuracy of better than 100 ns.

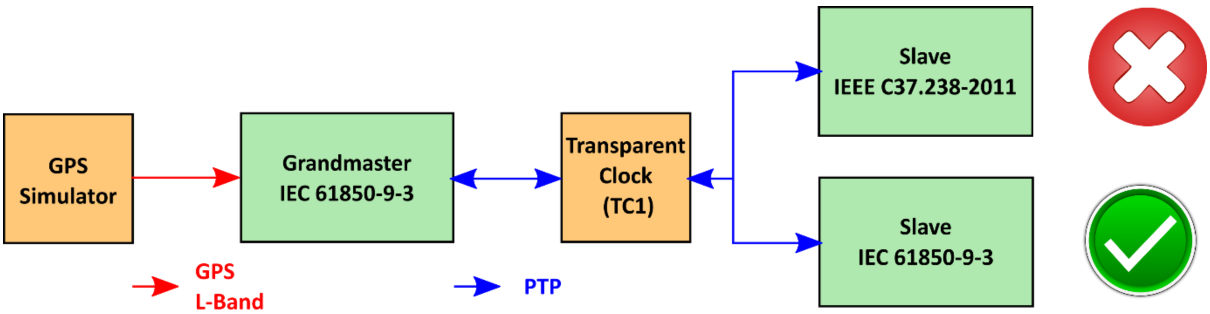

Figure 11 – Single IEC 61850-9-3 grandmaster

The test was then repeated with an IEC 61850-9-3 grandmaster. As shown in Figure 11 the IEEE C37.238 slave did not lock to the IEC 61850-9-3 grandmaster since the grandmaster did not send out the IEEE C37.238 specific TLV. Again this was the expected result.

To analyse what happens when two grandmaster clock compliant to different profiles are operated in the same network, a setup involving two grandmaster clocks was setup. The BMCA switch over was triggered by simply changing the priority1 field of the clocks.

Figure 12 below shows the described setup. Grandmaster A (IEEE C37.238-2011) has the better priority and therefore becomes the master for both connected slave clocks. Grandmaster B (IEC 61850-9-3) has a lower priority and therefore switches itself to passive mode. This is the expected and correct behaviour.

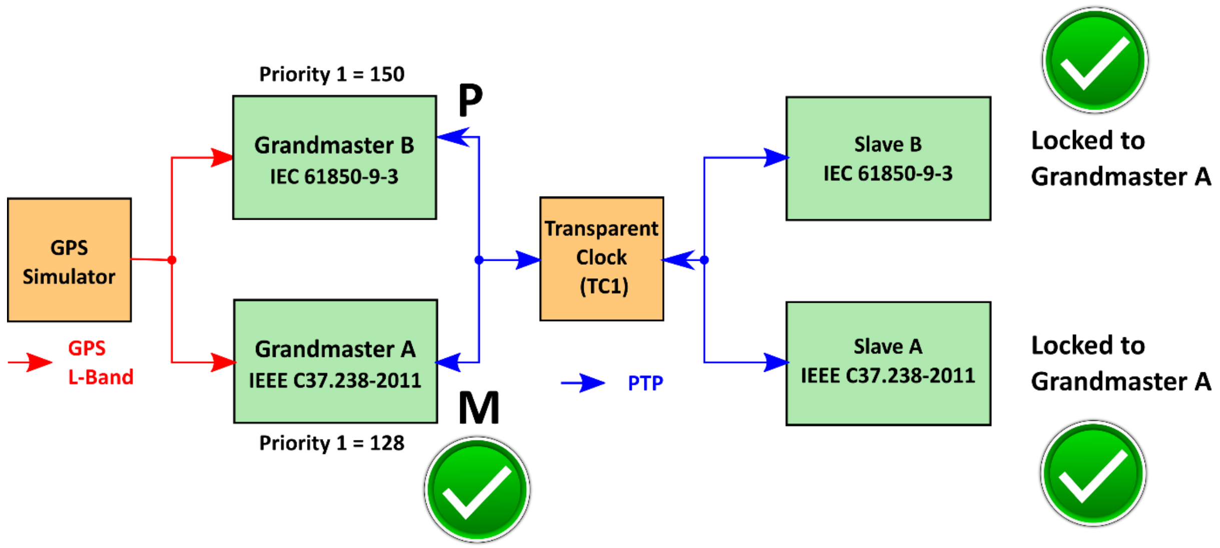

Figure 12 – BMCA test with IEEE C37.238 as the best clock

In the next step the test was repeated with changed priorities. Now the Grandmaster B (IEC 61850-9-3) has the better priority while Grandmaster A (IEEE C37.238-2011) has the lower priority. At the first glance the result as shown in Figure 13 is surprising. Both clocks announce themselves as grandmasters and the slave clocks lock themselves to different grandmasters. The reason for this is that Grandmaster A (IEEE C37.238) ignores all grandmasters not sending out the IEEE C37.238 TLV and therefore sees itself as the best clock in the network. On the other hand grandmaster B correctly sees itself as the best clock in the network and announces itself as the grandmaster. On the slave side Slave A ignores grandmaster B because of the missing TLV. Slave B locks correctly to Grandmaster B the best clock in the network.

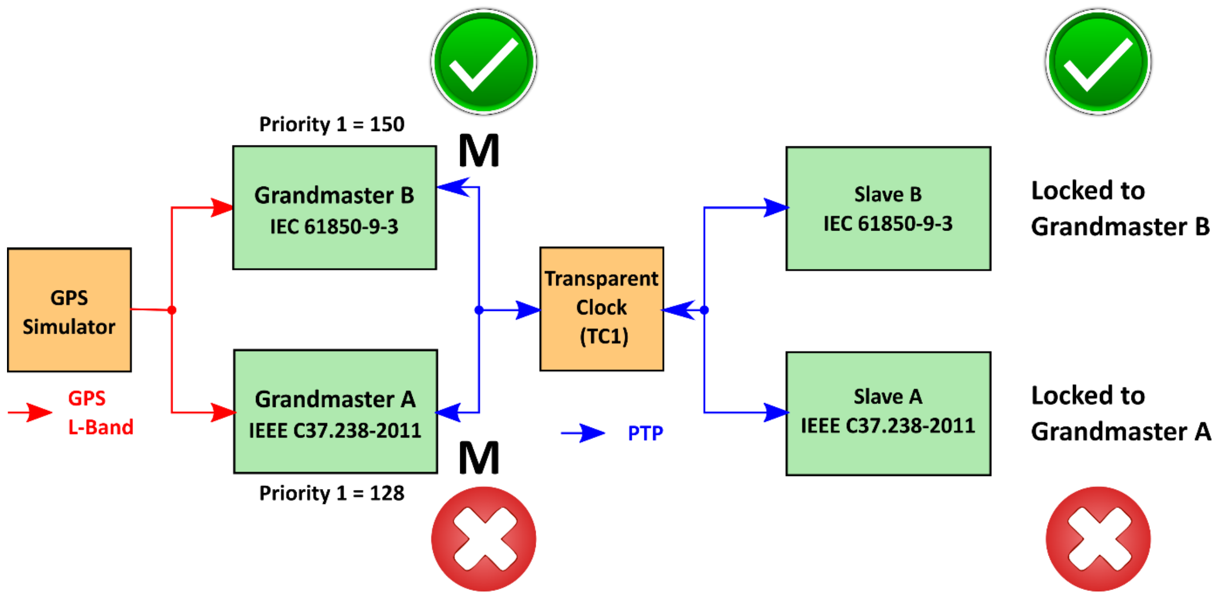

Figure 13 – BMCA test with IEC 61850-9-3 as the best clock

The tests performed during the IOP showed that there are interoperability issues between the two examined profiles. So mixing these profiles in the same network is not a good idea. However, this situation might change in the near future.

What will happen next?

Figure 14 shows the current standardization situation for IEEE 1588 (PTP) and the two discussed profiles. As it can be seen from the graph a new version of PTP is under definition. Despite officially referred to as PTPv3 it is nick named PTPv2.1 since this time a downwards compatibility to IEEE 1588-2008 is targeted by the working group.[13]

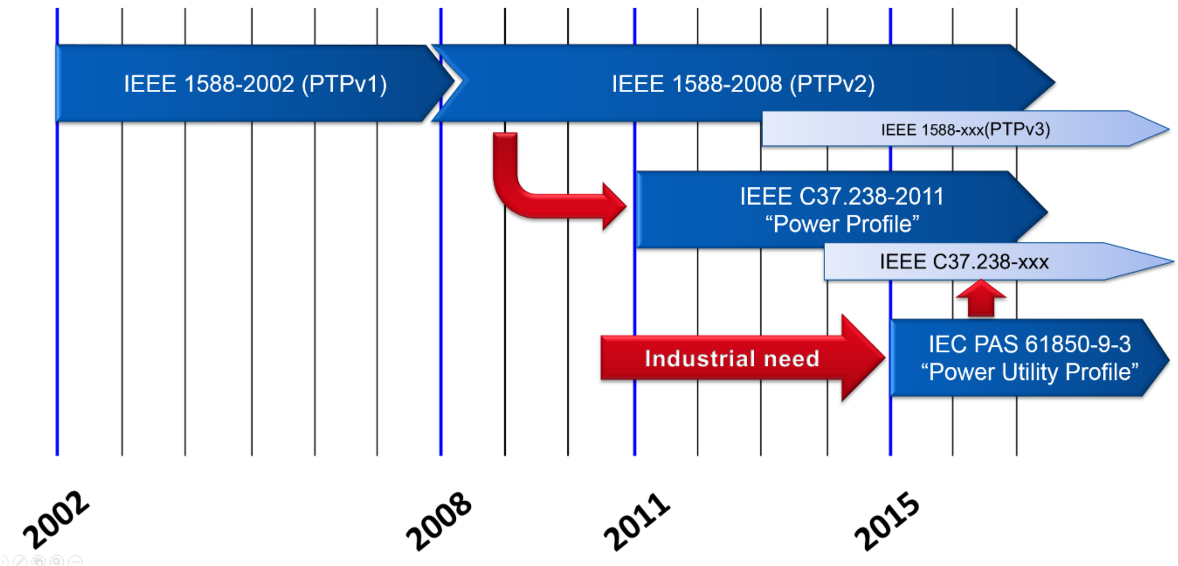

Figure 14 – PTP and Power Profile related standardisation situation

In September 2015 right at the time of the IEC 61850 IOP in Brussels a new draft for a revised Power Profile (IEEE P37.238/D15) was circulated. In this draft some major issues experienced in the last years have been addressed. The new draft defines IEEE C37.238 as an extension to IEC 61850-9-3. It defines a basic IEC 61850-9-3 mode and an extended IEEE C37.238 mode. Further on all clocks compliant to the new proposed profile will be able to be used in IEC 61850-9-3 infrastructures without restrictions. [19]

To achieve this cross profile compatibility the following changes were made in the draft:

- VLANs are no longer part of the standard.
- The use of TLVs now depends on the chosen mode
    - no mandatory TLVs for IEC 61850-9-3 mode
    - mandatory profile specific TLVs for IEEE C37.238 mode.
- The default Best Master Clock Algorithm is used – grandmasters not sending the TLVs are no longer ignored. Hence, the problem detected at the IOP 2015 in Brussels will be solved if the draft is accepted.
- Definition of the profile specific SNMP-MIB have been removed.

According to [19] the advantages offered by the IEEE C37.238 mode is a continuous monitoring of Time Inaccuracy and optionally Local Time based on UTC.

Conclusion

With the release of IEC 61850-9-3 a lean, easy to implement and easy to use PTP profile was introduced to the IEC 61850 community. PTP in accordance to IEEE 1588 is now an official part of IEC 61850 and can be utilized for all time critical applications fulfilling the highest time performance class requirements without the need of decentralized GPS disciplined clocks or a separate time distribution network. The planned changes for IEEE C37.238 and the targeted compliance with IEC 61850-9-3 is also a step in the right direction to ensure a stable standardization situation. If the current draft for IEEE C37.238 is accepted a battle of profiles will have been avoided before it even started.

The Authors

Bernhard Baumgartner obtained his engineering degree in 1990 from the technical college for electronics and telecommunications in Rankweil, Austria. In the following years he worked as development engineer and product manager for major companies in the digital broadcast industry. During his time as hardware developer he was intensively engaged with time synchronizing technologies for digital TV and radio transmitters in single frequency networks. Since 2006 he works for OMICRON electronics in Klaus, Austria, where he is responsible for the business segment OMICRON Lab.

Christian Riesch studied Electrical Engineering at the Vienna University of Technology (VUT), Austria and received the Dipl.-Ing. (M.Sc.) degree and the Ph.D. degree in 2005 and 2009, respectively. From 2005 to 2009 he was a Research Assistant with the Institute of Sensor and Actuator Systems, VUT, performing research in the field of miniaturized sensor technology. Since 2009 he is with the hardware development team of OMICRON electronics in Klaus, Austria, and works on solutions for the time synchronization of measurement systems.

Wolfgang Schenk studied Electrical Engineering at the Munich University of Applied Sciences (MUAS), Germany and received the Bachelor degree in Electrical Engineering (B.Eng.) in 2005. In 2007 he received his Master degree in Electrical and Microsystems Engineering (M. Eng.) at the OTH Regensburg, Germany. From 2007 to 2012 he worked as Hardware Test Engineer and Hardware Developer for major companies active in the automotive industry. In 2013 he joined OMICRON Lab, as Sales and Application Engineer for IEEE1588 PTP Timing Solutions.

References

[1] Howse D, “Greenwich Time and the Longitude.” Philip Wilson Publishers Ltd, 1997

[2] McCarthy D, Seidelmann K, ”TIME From Earth Rotation to Atomic Physics.” Wiley-VCH Verlag GmbH & Co.Weinheim, 2009

[3] “The Internatonal System of Units (SI)“, 8th Edition, Bureau International des Poids et Mesures, 2006

[4] Recommendation ITU-R TF.460-6 “Standard-frequency and time-signal emissions”, ITU Radiocommunication assembly, 1970-2002

[5] ITU.int, “Coordinated Universal Time (UTC) to retain “leap second””, https://www.itu.int/net/pressoffice/press_releases/2015/53.aspx, ITU, retrieved in April 2016

[6] “GPS Interface Specification, Navstar GPS Space Segment/Navigation User Segment Interfaces (IS-GPS-200G)”, Revision G, GPS Directorate, 21 September 2011

[7] Baumgartner B, Riesch C, Schenk W, “GPS receiver vulnerabilities - urban legends or sad, hard truth?”, PAC World Conference 2014, Zagreb, Croatia, 2014

[8] PRC-018-1, “Disturbance Monitoring Equipment Installation and Data Reporting” NERC, 2006

[9] Baumgartner B, Riesch C, Rudigier M, “Implementation and transition concepts for IEEE 1588 precision timing in IEC 61850 substation environments”, SASPC Conference 2012, Cape Town, South Africa, 2012

[10] IEEE 1588-2008, “IEEE Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems”, IEEE, 2008

[11] IEC 61850-5:2013, “Communication networks and systems for power utility automation - Part 5: Communication requirements for functions and device models”, IEC, 2013

[12] IEC 61850 Ed.2, “Communication networks and systems in substations”, IEC

[13] Eidson J C, “Time Synchronisation over networks, IEEE 1588 and Applications”, KTH Lecture, 2015

[14] Weibel H, “Technology Update on IEEE 1588 - The Second Edition of the High Precision Clock Synchronization Protocol”, Embedded World 2009, Nürnberg, Germany, 2009

[15] “Publicly available Specifications PAS”, http://www.iec.ch/standardsdev/publications/pas.htm, IEC, retrieved in May 2016

[16] IEC PAS 61850-9-3 “Communication Networks and systems for power utility automation – Part 9-3: Precision time protocol profile for power utility automation”, Edition 1.0, IEC, 2015

[17] IEEE C37.238-2011 “IEEE Standard Profile for Use of IEEE 1588™ Precision Time Protocol in Power System Applications”, IEEE, 2011

[18] UCA International User Group “Final Report: 2015 IEC 61850 IOP”, UCA International User Group, Belgium, 2015

[19] P37.238/D15 “Draft Standard Profile for Use of IEEE 1588 Precision Time Protocol in Power System Applications”