Standard Profile for Use of IEEE Std 1588-2008 Precision Time Protocol (PTP) in Power System Applications

IEEE PES PSRC Working Group H7/Sub C7

April 10, 2013, College Station, TX, USA

Outline

- IEEE Std C37.238 scope and status
- Introduction to IEEE 1588
- IEEE 1588 parameters
- IEEE C37.238 parameters
- Conclusion

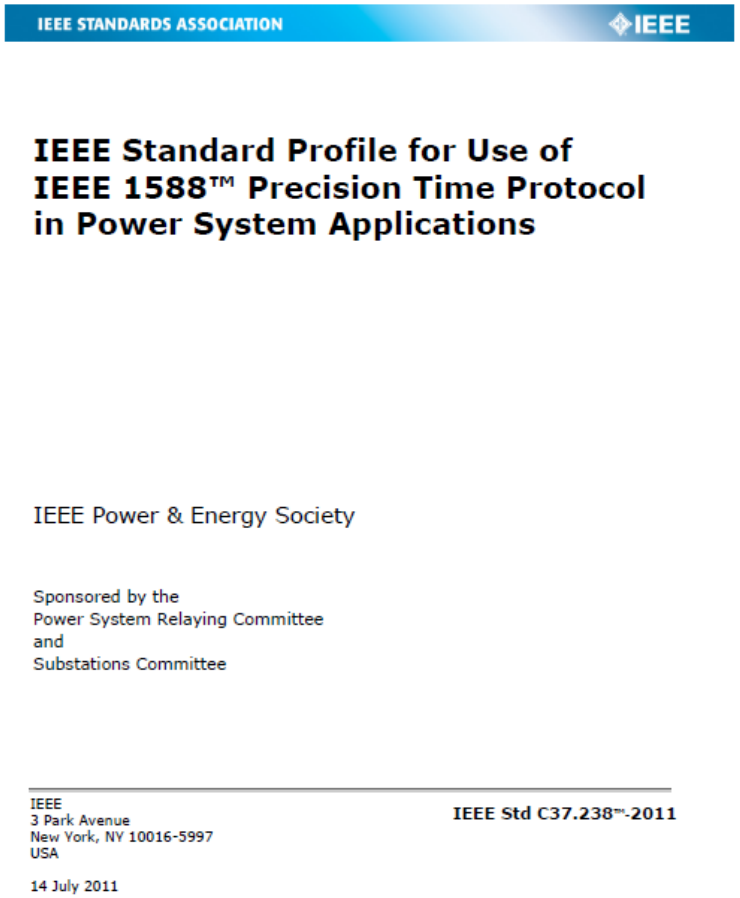
IEEE C37.238 Scope and Purpose

- This standard specifies a common profile for the use of IEEE 1588 Precision Time Protocol (PTP) in power system protection, control, automation, and data communication applications utilizing an Ethernet communications architecture.

- The purpose of this standard is to facilitate adoption of IEEE Std 1588-2008 for power system applications requiring high precision time synchronization.

IEEE C37.238 Status

- Approved IEEE 1588/IEC 61588 standard calls for generation of industry-specific profiles
- IEEE C37.238 Power Profile published in July 2011
- Produced by IEEE PSRC WG H7/Sub C7 in co-operation with IEC TC57 WG10
- WG philosophy
  - Reduce mandatory features
  - No options unless justified


IEEE STANDARDS ASSOCIATION IEEE

IEEE Standard Profile for Use of IEEE 1588™ Precision Time Protocol in Power System Applications

IEEE Power & Energy Society

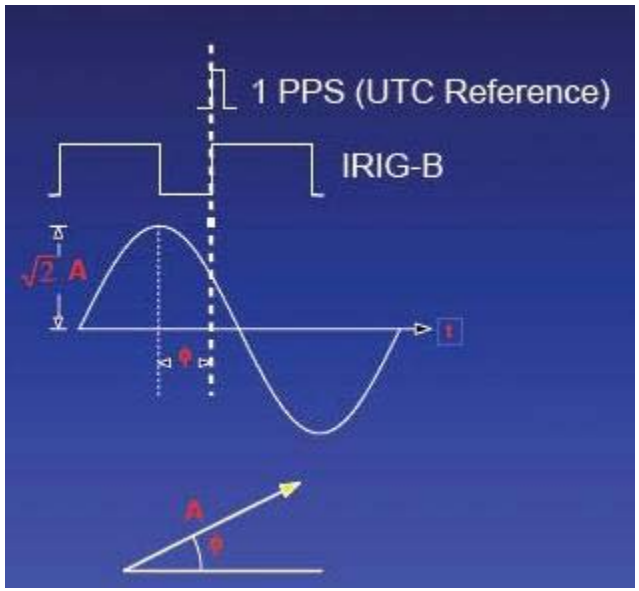
Sponsored by the
Power System Relaying Committee
and
Substations Committee

IEEE
3 Park Avenue
New York, NY 10016-5997
USA

14 July 2011

IEEE Std C37.238™-2011

Application Examples



Synchrophasors

- Synchronized phasor measurements (magnitude, angle)
- Used for metering, possibly protection function
- Inside substation and for wide geographic area
- 1% Total Vector Error (26 µs for 60Hz systems)
- Specified in IEEE C37.118.1/2 -2011
- **1 µs accuracy of absolute time**

Line Differential Protection

- Critical protection function
- Compares samples taken at the same time
- Sampling rate must be synchronized
- Tens of samples per cycle
- **1 µs accuracy of relative time**

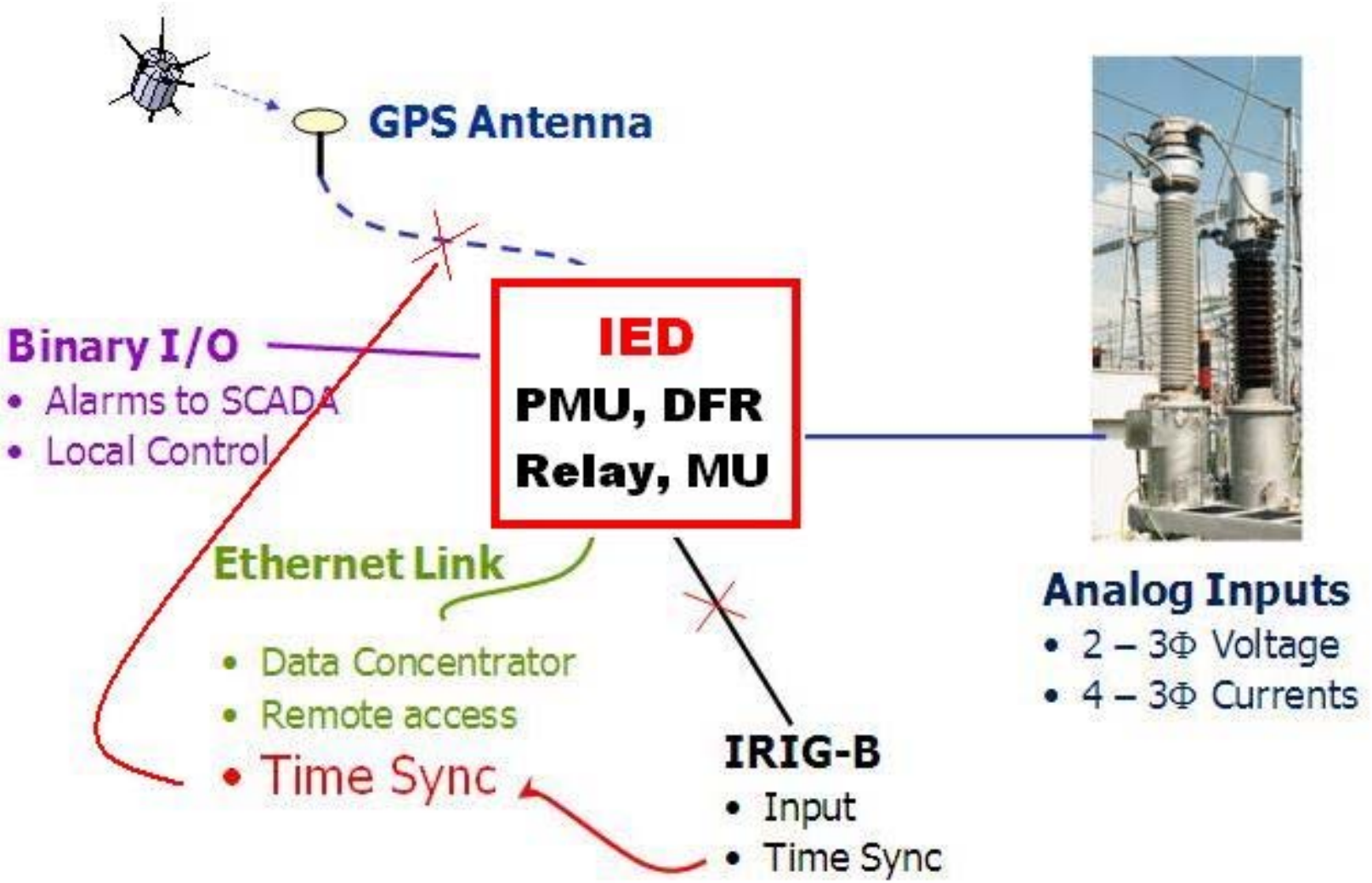
Sampled Analog Values

- Merging Units sampling must by synchronized
- IEC 61850-7-2 (Service Models) IEC 61850-9-2 (Mapping to Layer 2 /Ethernet)
- **1 µs accuracy of relative time**

SCADA, Events recording

- **1 ms accuracy of absolute time**

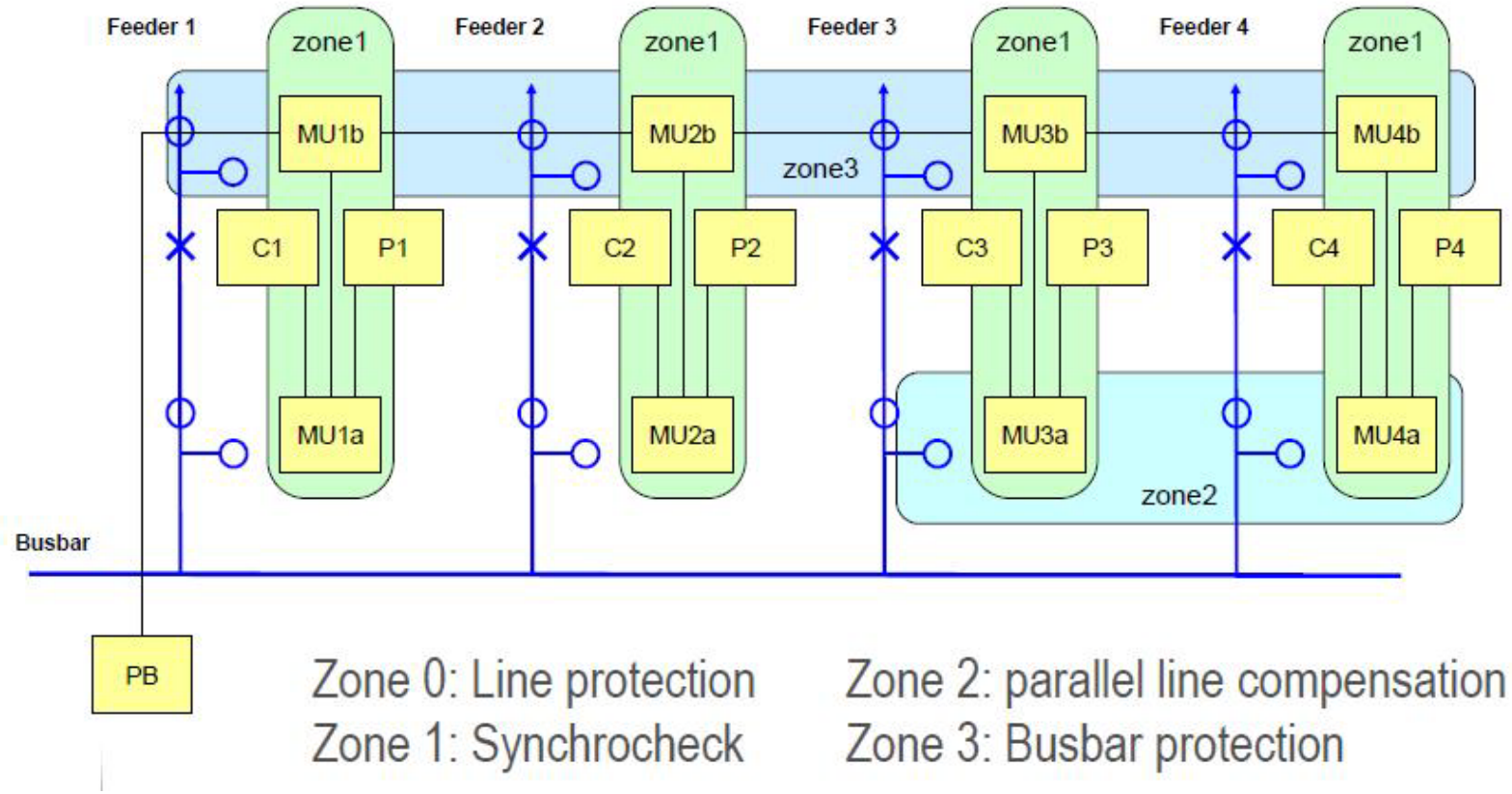
IED Time Synchronization Alternatives



Time Distribution Technologies

	IRIG-B	(S)NTP	PTP
Accuracy (typical)	1-10μs	100μs-1ms	100ns-1μs
Transport media	Dedicated cable	Ethernet cable	Ethernet cable
Protocol style	Master-slave	Client-server	Master-slave
Built in latency correction	No	Yes	Yes
Set-up	Configured	Configured	Self-organizing, or configured
Update intervals	1 second	minutes	10ms – 1 second
Specialized hardware	Required	No	Required

Protection/Synchronization Zones

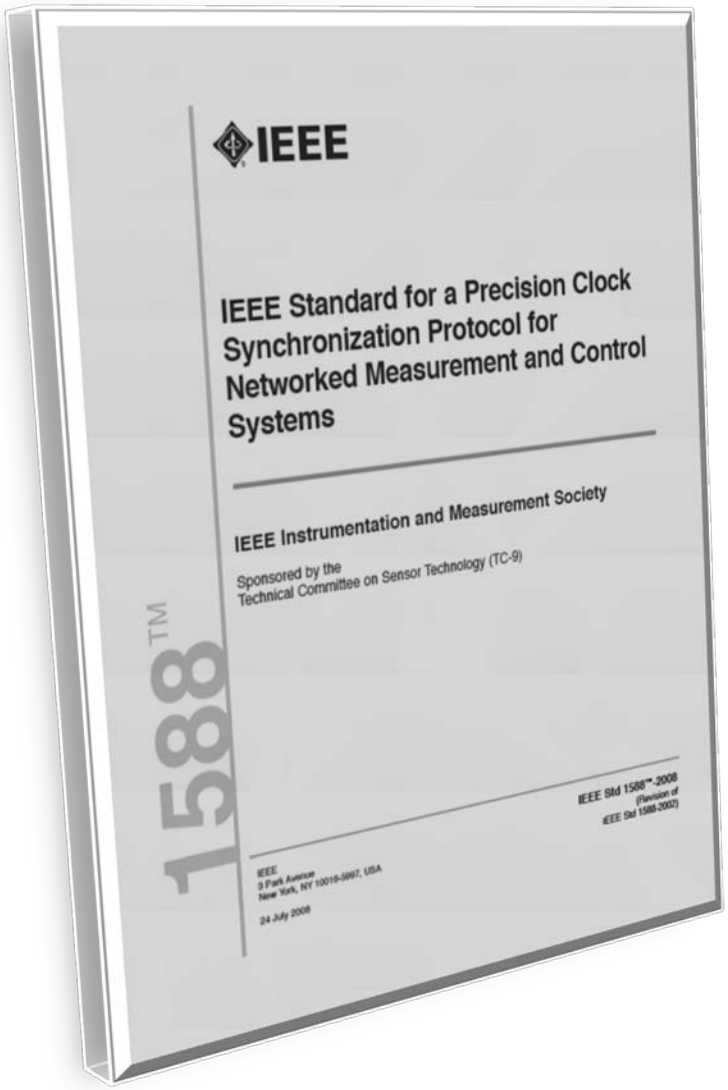


Source: PSRC WG H7 Presentation “Time Synchronization and Network Topology” by Christoph Brunner, January 14, 2009

IEEE 1588 Introduction

- IEEE 1588-2008 standard
- Time distribution over Ethernet
- Message-based protocol
- Delay compensations
- Auto selection of best master

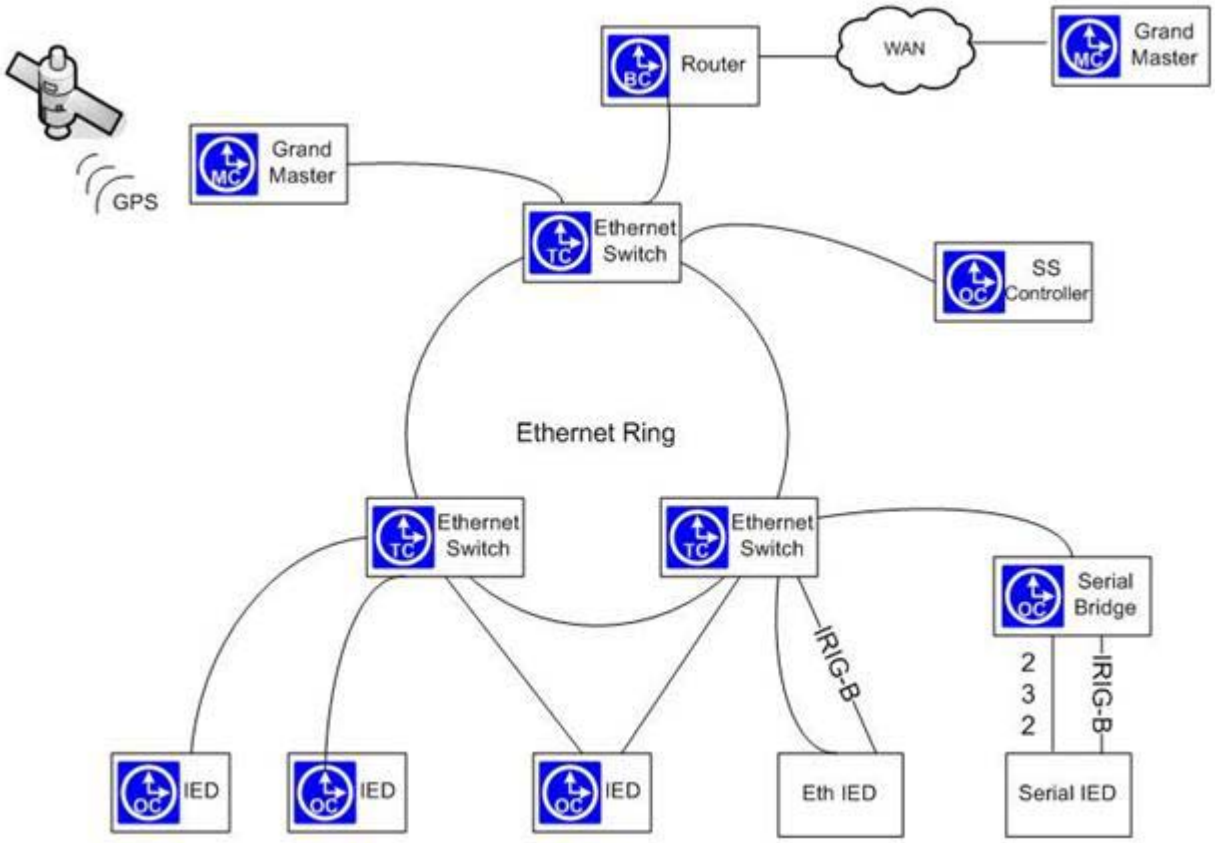
IEEE 1588-2008 Standard



IEEE 1588-2008 ("version 2")

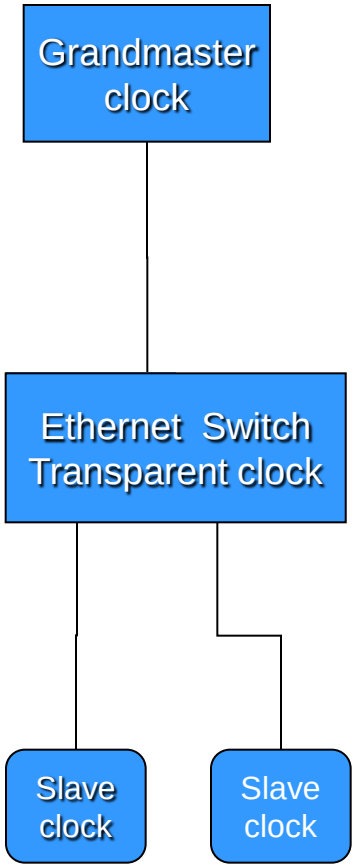
- Defines Precision Time Protocol (PTP)
- Used to synchronize independent clocks on separate nodes of a distributed system to a high degree of precision,
- defines how to transfer precise time over networks.
- Uses "***Profiles***"
  - Protocol features/settings/ranges grouped into industry adopted "standards"
  - Defines only the "*Default Profile*"
  - Industry-specific profiles can be defined by IEEE or other standardization organizations

Synchronization Network Example



Source: PSRC WG H7 Presentation “IEEE 1588v2 Profile for Power Systems” by Roger Moore, September 2008

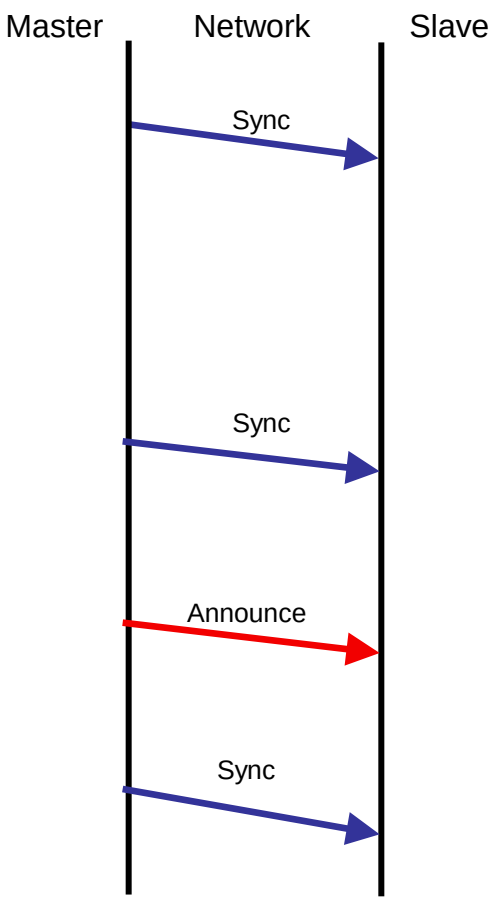
PTP Devices



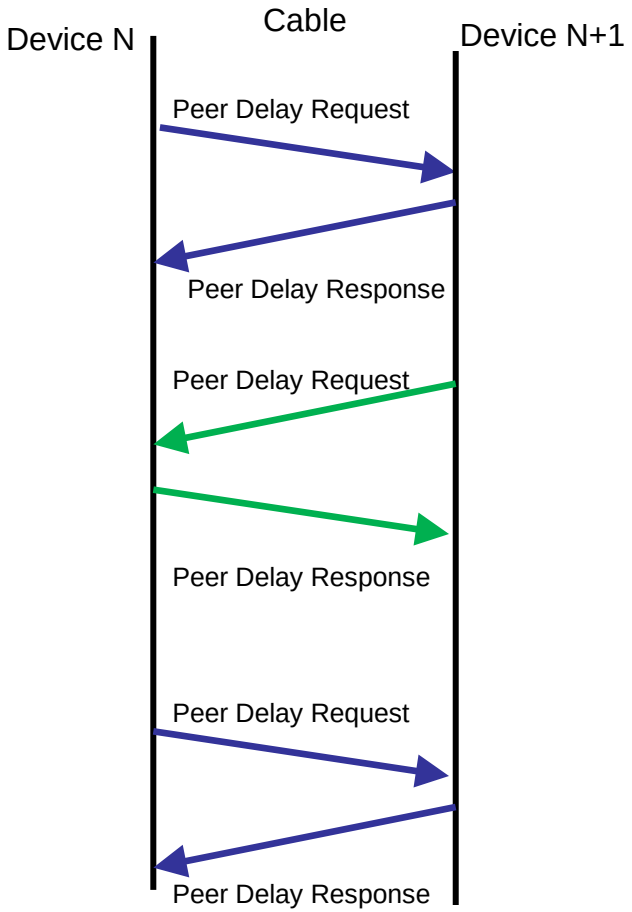
- Time transferred from Grandmaster to Slaves
- Transparent clock
  - Ethernet switch with improved PTP accuracy
  - Corrects for its delay
- Ordinary clock
  - A clock with single connection
  - Can be Master or Slave
  - Integrated into application devices such as IEDs

PTP Messages

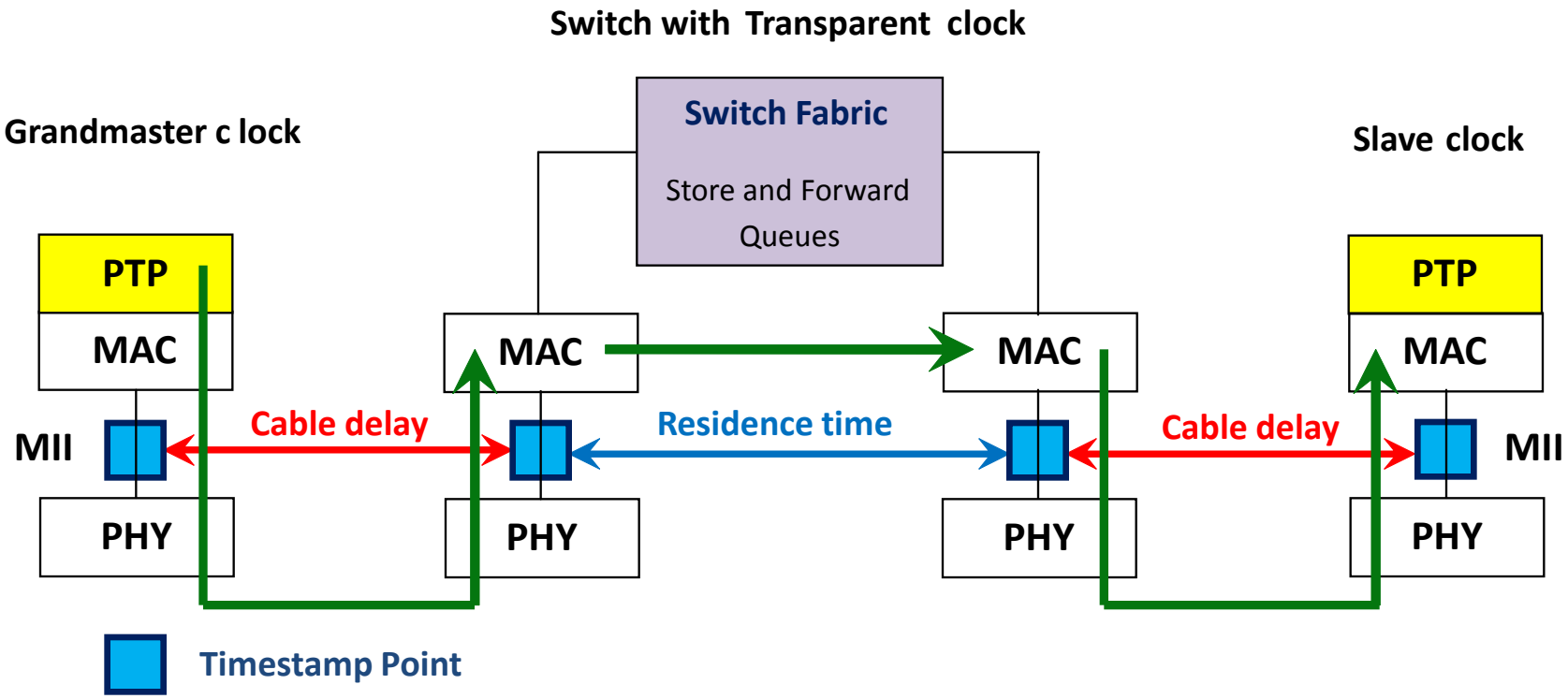
Master to slaves



Adjacent Devices

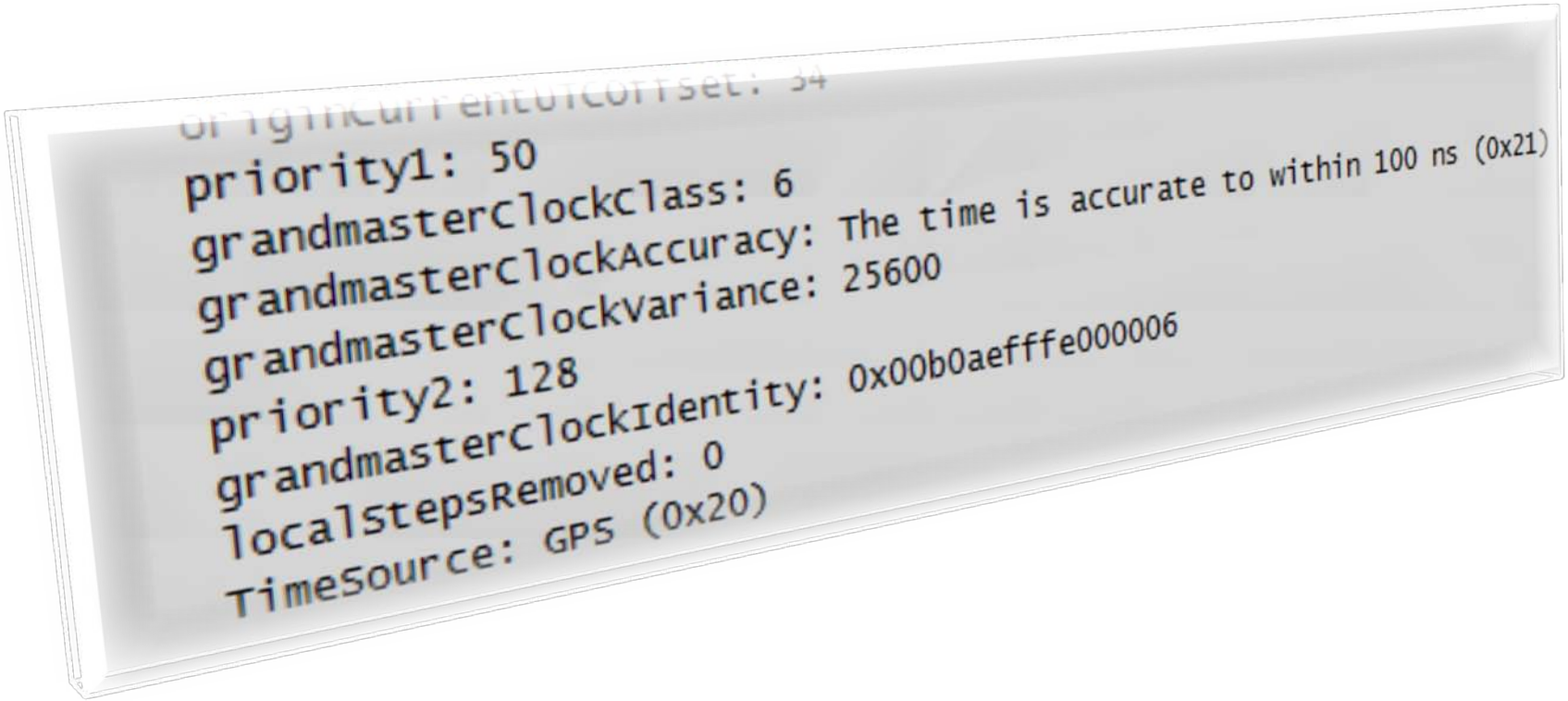


PTP Delay Compensation



Best Master Clock Algorithm

The algorithm select the best master, based on information all devices receive in the *Announce* message:



- The unique clockID is the tie-breaker.

IEEE 1588 Parameters

- One-step and two-step clocks
  - initial reason is 2-step silicon availability
  - Clock Types
  - grandmaster-capable, transparent and slave-only clocks
- Multicast communications and Layer 2 mapping
  - special Destination MAC Address Pdelay messages
- 1 s intervals for all PTP messages
- Peer-to-peer path delay measurement
- Default Best Master Clock Algorithm
  - optional for slave-only clocks
- Local Time TLV
  - to communicate local time to end devices

IEEE C37.238 Parameters

- Pdelay is optional for slave-only clocks
- IEEE 802.1Q tags
  - support VLAN and Priority as in IEC 61850-9-2
- IEEE_C37_238 TLV
  - configurable 8-bit Grandmaster ID
  - GrandmasterTimeInaccuracy and NetworkTimeInaccuracy
- IEEE C37.238 MIB
  - SNMP-based Management Support
- Steady-state performance requirements
  - 1 µs time accuracy over 16 network hops
- Mappings for IEEE C37.118 and IEC 61850 protocols
  - informative Annex C
- IRIG-B replacement mode

Grandmaster ID

- **Purpose**
  - To detect synchronization to different grandmasters during grandmaster change states
  - To communicate 8-bit ID of the current master
  - To support mapping to IEC 61850 smpSynch parameter

- **Definition**

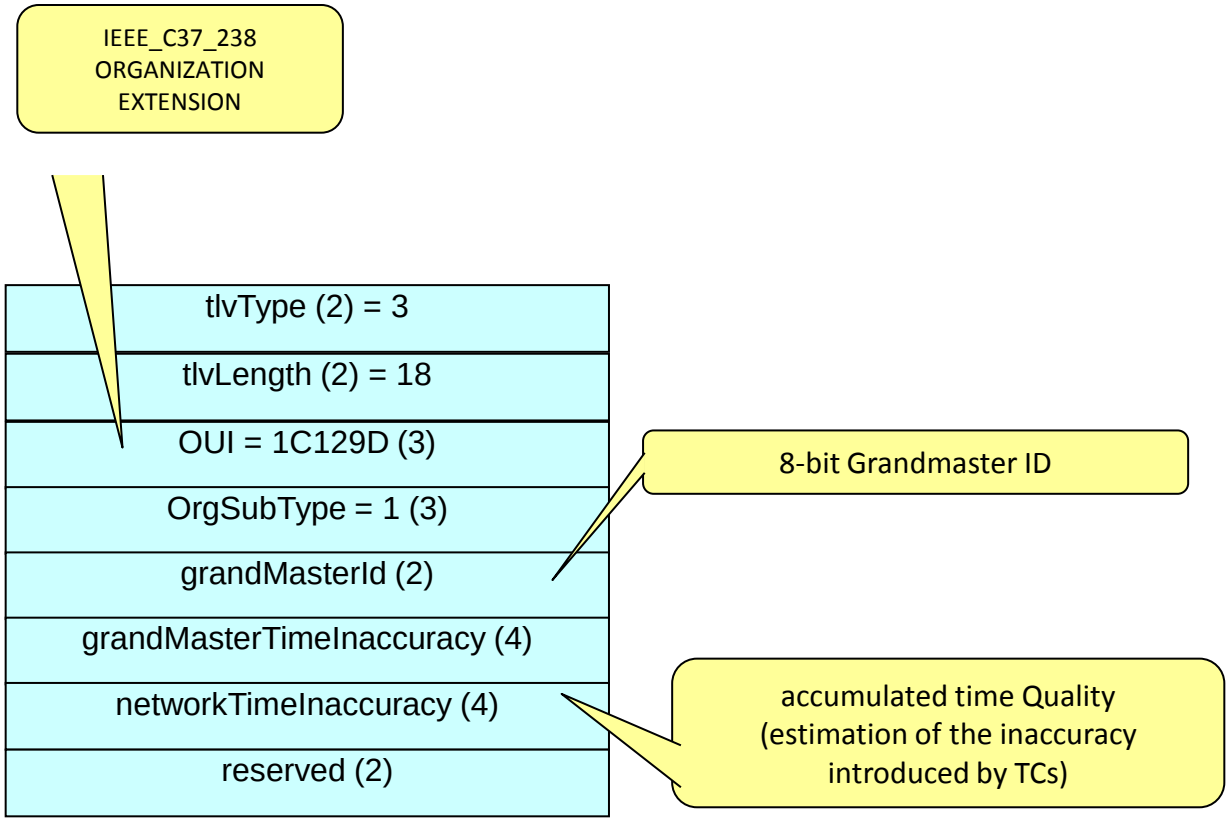
  grandmaster clock: Within a domain, a clock that is the ultimate source of time for clock synchronization using the protocol.

- **Location**
  - IEEE_C37_238 TLV, attached to Announce Messages

- **Comments**

  - Requested by the TC38 WG37 Dynamic Merging Unit Behavior (IEC 61869-9/13)

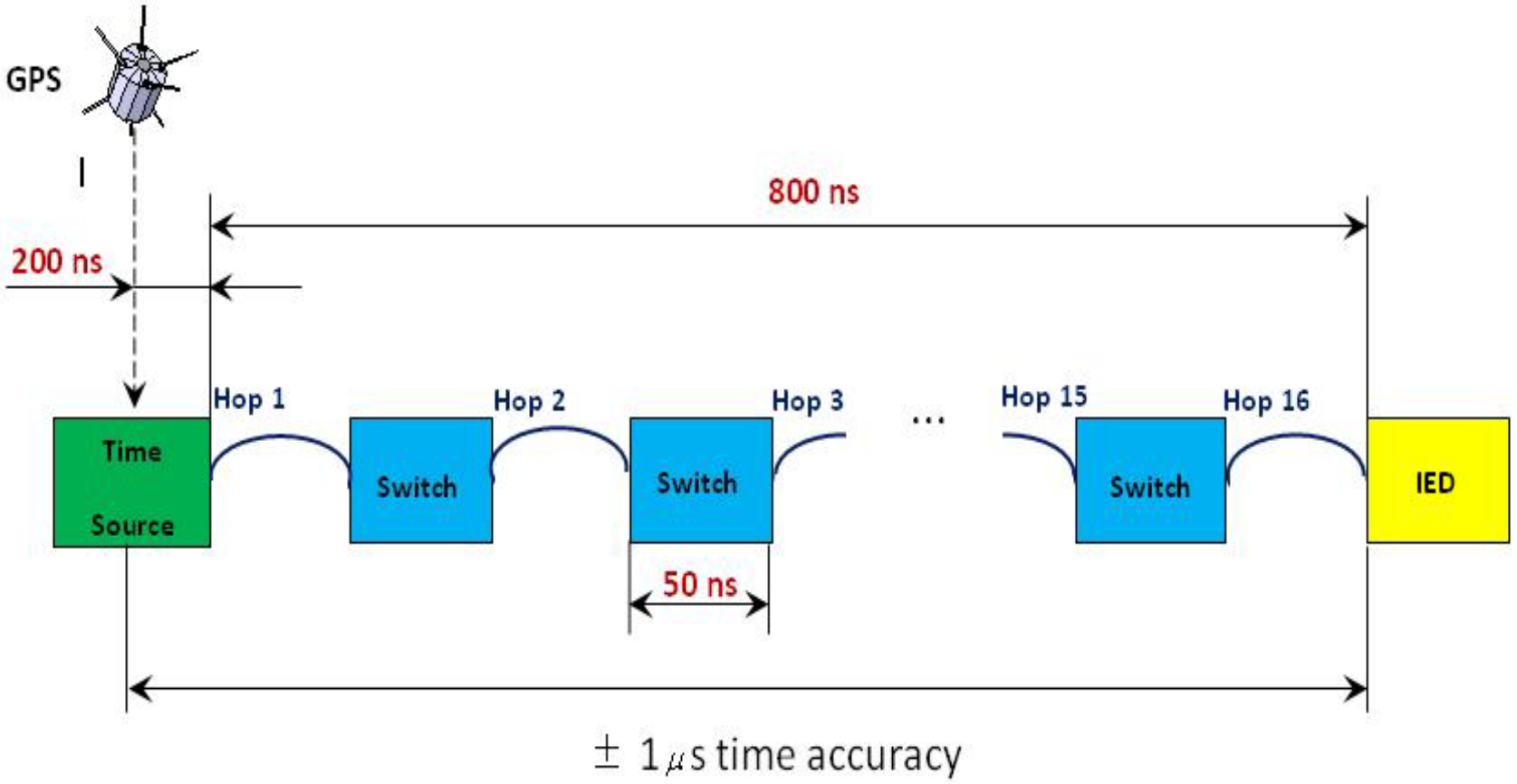
Example of IEEE C37.238 TLV



IEEE C37.238 MIB

- **Clock default and per port datasets**
  - local clock accuracy, two-step flag, slave-only
  - port enable, path delay, profile identity, network protocol
  - configurable Offset from Master Limit
- **Current dataset**
  - offset from the current grandmaster, added new 64–bit data type
- **Parent dataset**
  - current grandmaster identity, grandmaster accuracy
- **Time Properties dataset**
  - UTC offset, leap seconds, time traceable, local time info
- **Transparent clock default and per port datasets**
  - current grandmaster identity, enable syntonization, two-step flag
  - port path delay, faulty flag
- **Notifications**
  - change of grandmaster, change of port state, other profile detected
  - offset from Master exceeds configurable limit
  - added supplementary information, e.g. port ID

Steady-state Performance



IEEE C37.238 Testing Lemgo, March 2011

ISPCS PTP Plugfest

San Francisco, Sept 2012

17 out of 41 participating organizations tested IEEE C37.238

Conclusion

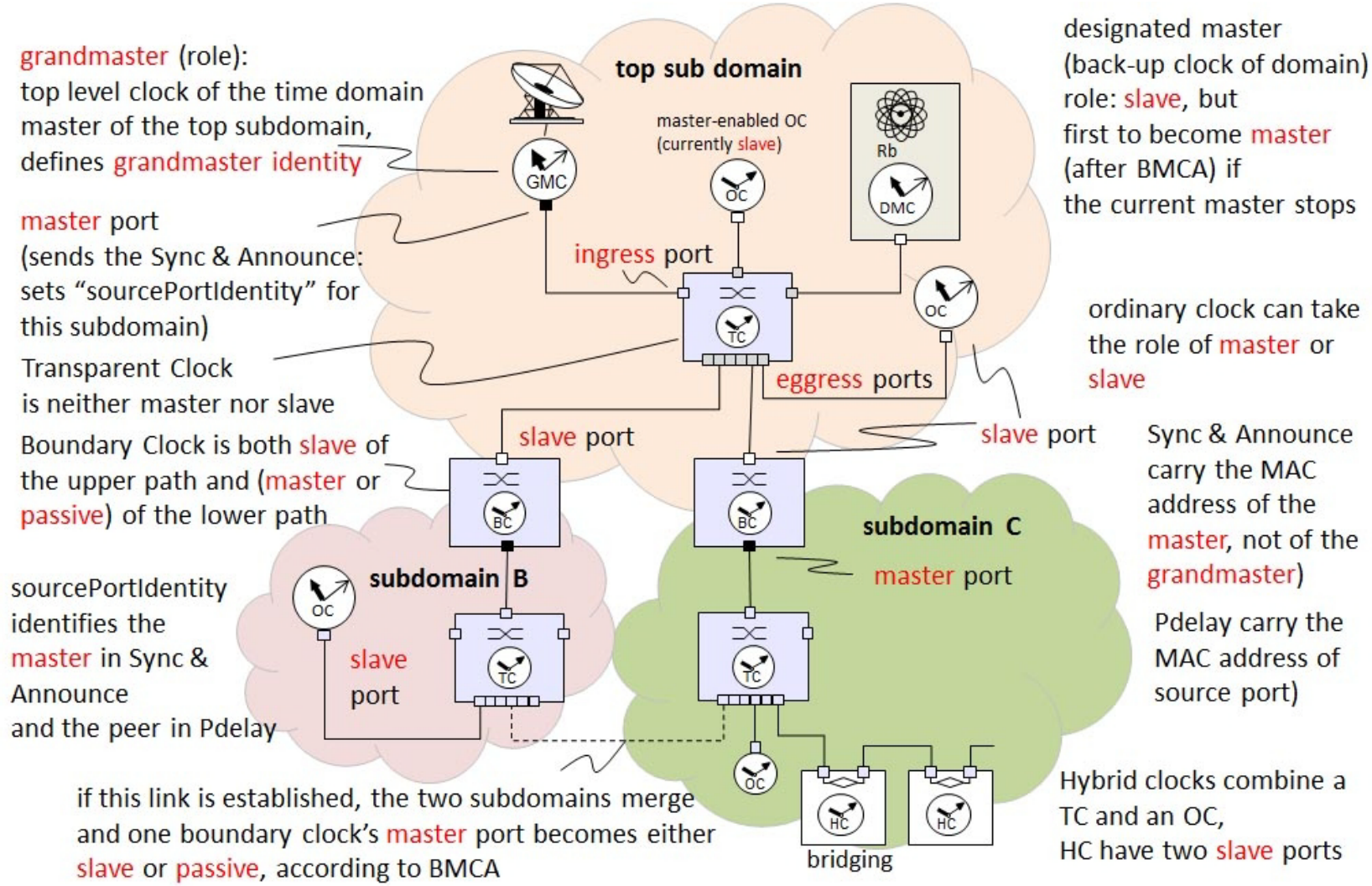
- IEEE C37.238-2011 standard specifies the PTP power profile for power system applications. The profile is optimized for use in specific power substation network architectures and meets timing requirements of the most strenuous power system applications.

Conclusion… cont

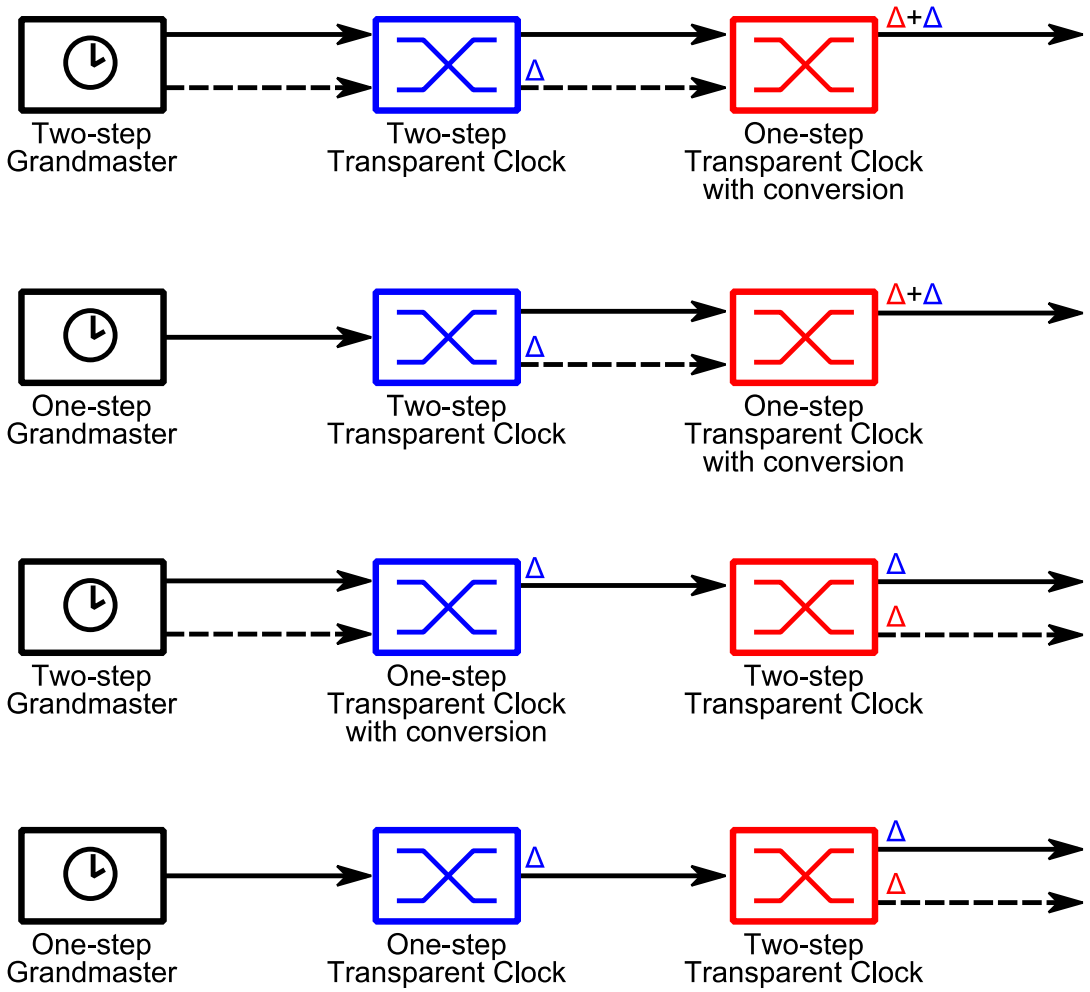
- The Working Group would like to thank all contributors who made the generation of the PTP power profile and this paper possible: Members and Guests of the IEEE PES PSRC Working Group H7, IEEE PES Substation Working Group C7, IEC TC57 WG 10, IEC TC38 WG37, IEEE PSRC Working Groups H11 and H19, and the whole power and timing communities for their dedication, guidance and support.

Backup Slides

IEEE 1588-2008 Definitions



One-step/Two-Step Conversion



Possible Usage of IEEE 802.1Q tags

- No VLANs (VID=0)
  - Priority-only frames
  - VID=0 is overwritten by switches
- VLANs (VID<>0) for traffic separation, e.g.
  - PTP in VLAN 1
  - Non-operational (video surveillance) in VLAN 5
- IEC DTR 61850-90-4 Draft provides network engineering guidelines