The New High Accuracy Default PTP Profile in the IEEE 1588 Draft Revision

Maciej Lipiński

European Organization for Nuclear Research

Agenda

- Overview
- High Accuracy Default PTP Profile
  - Optional features
  - Inter-operation with other Default PTP Profiles
  - Model of Local PTP Clock
- Summary

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- **Overview**
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White Rabbit

- Update of CERN's control and timing system
- **Sub-ns accuracy & sub-10ps precision**
- Based on IEEE 802.3, 802.1Q and **1588 (PTP)** with extensions:
  - L1 synchronization, similar to SyncE
  - Precise phase detection
  - Calibration and online estimation of asymmetries

  } Implementation

  - Extension of the PTP protocol to accommodate the above
- De-facto standard for timing & daq in scientific applications

IEEE1588 standard revision

- 2013: start of IEEE1588 revision
- Project Authorisation request:
  "…support for synchronization to better than 1 nanosecond"
- 5 sub-committees
- High Accuracy sub-committee
  - Focus on White Rabbit
  - Experts from industry and academia
  - Division of WR into self-contained parts
  - Definition of **Optional Features** and **PTP Profile** that allow WR-like implementation and WR performance

Agenda

- Some history
- **High Accuracy Default PTP Profile**
  - Optional features
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High Accuracy Default PTP Profile

High Accuracy Delay Request-Response Default PTP Profile

High Accuracy Default PTP Profile

High Accuracy **Delay Request-Response Default PTP Profile**

High Accuracy Default PTP Profile

Delay Request-Response Default PTP Profile

1. **Identification:** 00-1B-19-01-01-00
2. **PTP Attributes:** default values & ranges
3. **Optional features /mechanism**
   - BMCA: default
   - Mechanism: request-response by default, peer-to-peer allowed
   - Required options: none
   - Prohibited options: none
   - Permitted options: all*****
4. **Clock physical requirements:** frequency accuracy below 0.01%

***** Optional feature **inactive (disabled)** by default

High Accuracy Default PTP Profile

High Accuracy Delay Request-Response Default PTP Profile

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2. **PTP Attributes:** default values & ranges
3. **Optional features /mechanism**
   - BMCA: default
   - Mechanism: request-response by default, peer-to-peer allowed
   - Required options: Annex O, Q.3, 16.7, 16.8, 17.6*, masterOnly*
   - Prohibited options: 16.5
   - Permitted options: all others*
4. **Clock physical requirements:** frequency accuracy below 4.6ppm
5. **Default values & ranges for attributes of required options**
6. **High Accuracy model of Local PTP Clock**
7. **Information on inter-operation with other Default PTP Profiles**

* Optional feature **inactive (disabled)** by default

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Options required/prohibited by HA Profile

Required and active by default:

- L1-based sync. performance enhancements **[Annex O]**
- Configurable correction of timestamps **[16.7]**
- Calculation of the <delayAsymmetry> for certain media **[16.8]**
- Requirements of Q.3 **[Annex Q]**

Required and inactive by default:

- Mechanism for external config. of a PTP Instance's PTP Port state **[17.6]**
- masterOnly mode **[9.2.2.2 & 8.2.15.5.2]**

Prohibited:

- Isolation of PTP Instances **[16.5]**

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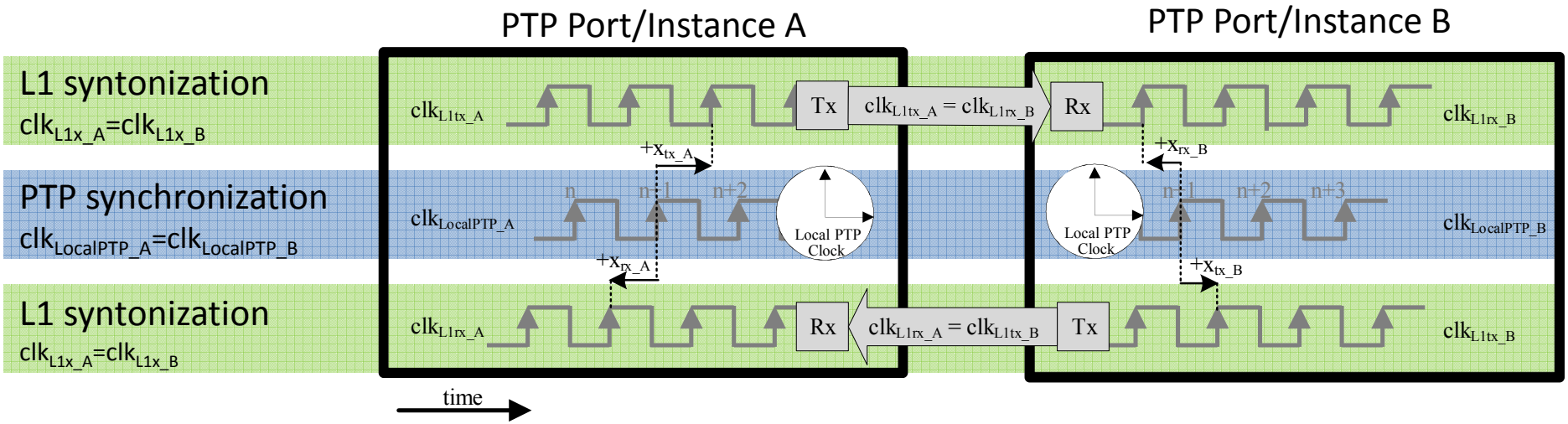
L1 synchronization enhancements (L1Sync)

- Supports **cooperation** & defines **relationship** between
  - PTP-based **synchronization** and
  - L1-based **syntonization,** e.g. Synchronous Ethernet
- Provides **configuration** and **status** of the PTP-L1 relationship
- IMPORTANT: Requires **hardware support**

PTP synchronization and L1 syntonization



PTP synchronization and L1 syntonization

L1 Syntonization
$clk_{L1x\_A}=clk_{L1x\_B}$

PTP synchronization
$clk_{LocalPTP\_A}=clk_{LocalPTP\_B}$

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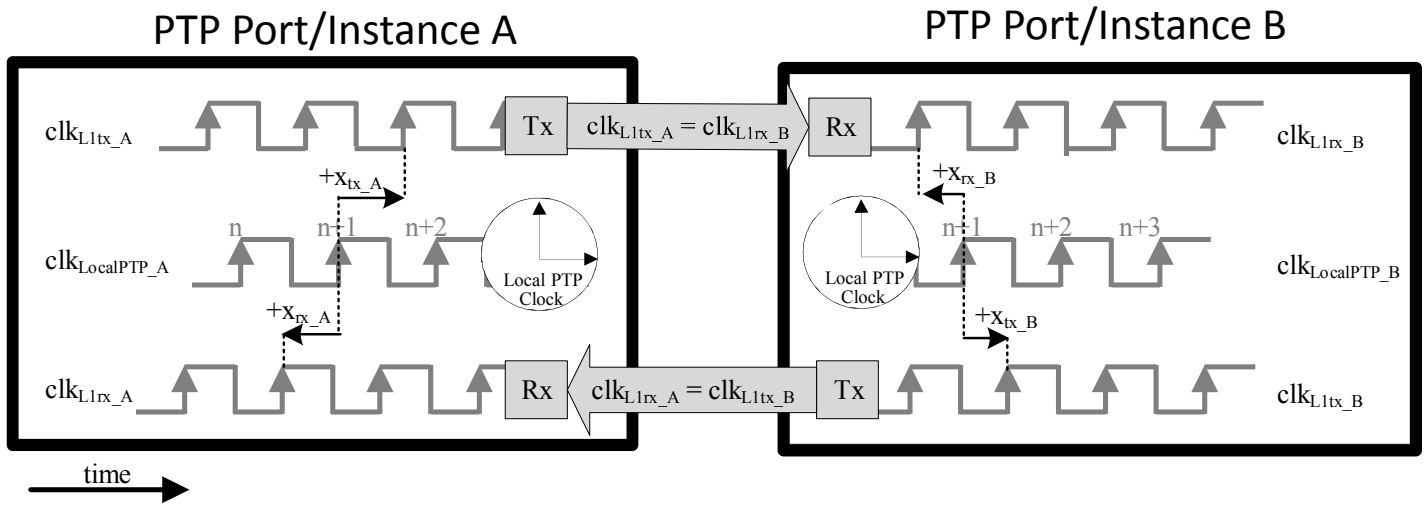

Transmit coherent port:

Receive coherent port :

Congruent port :

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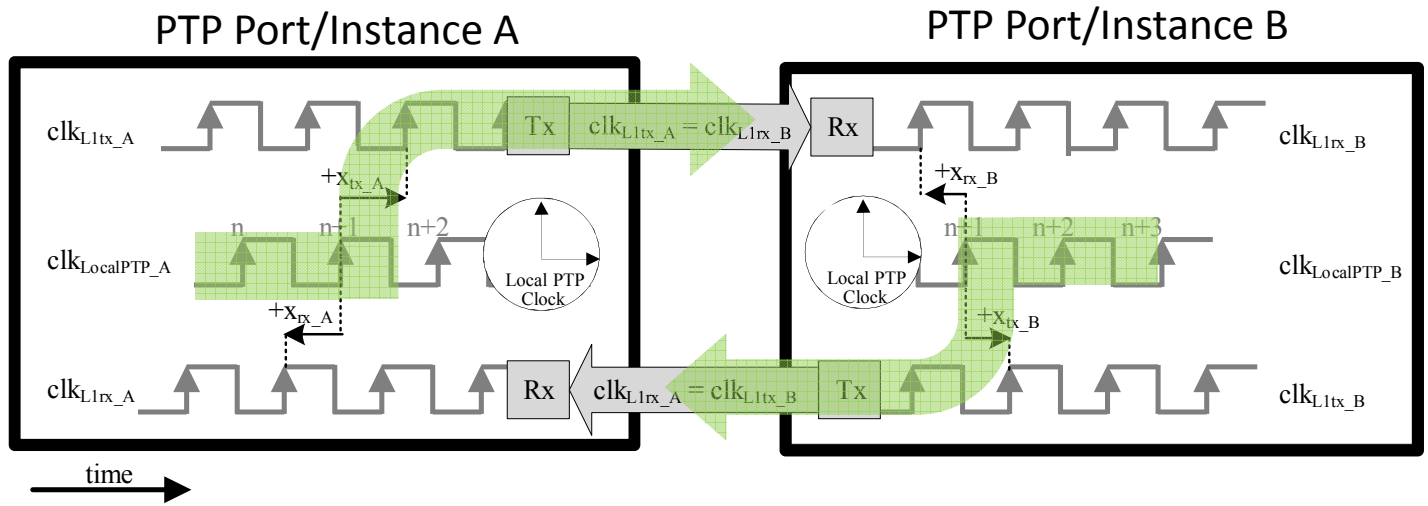

Transmit coherent port: x_{tx} = constant, so clk_{L1tx}= $clk_{LocalPTP}$

Receive coherent port :

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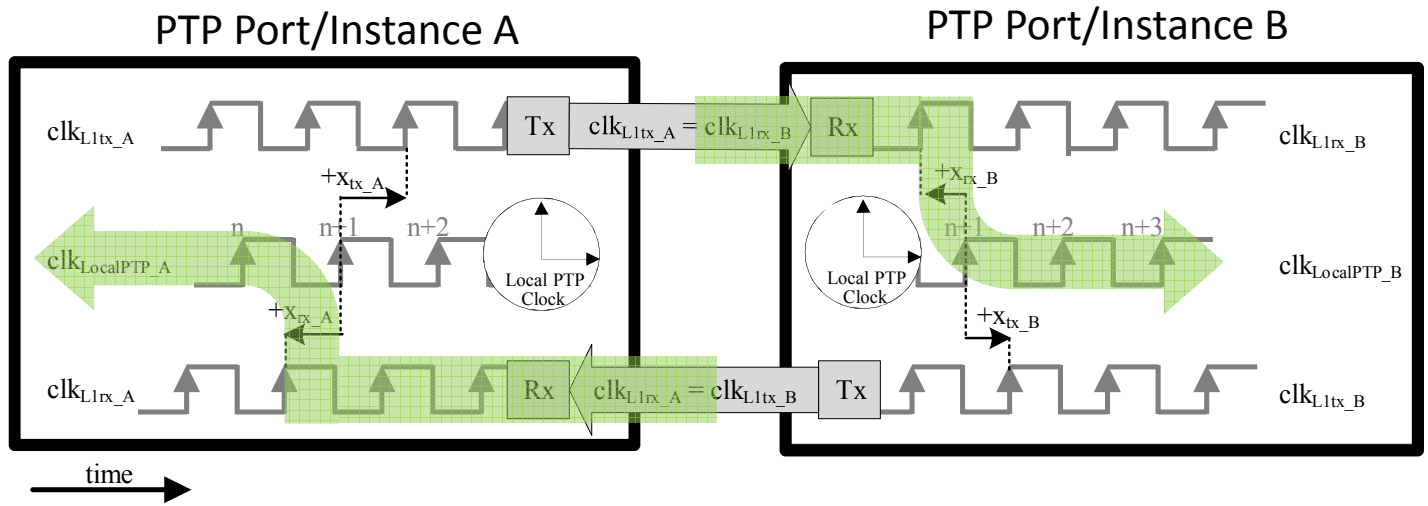

Transmit coherent port: x_{tx} = constant, so clk_{L1tx}= $clk_{LocalPTP}$

Receive coherent port : x_{rx} = constant, so clk_{L1rx}= $clk_{LocalPTP}$

Congruent port :

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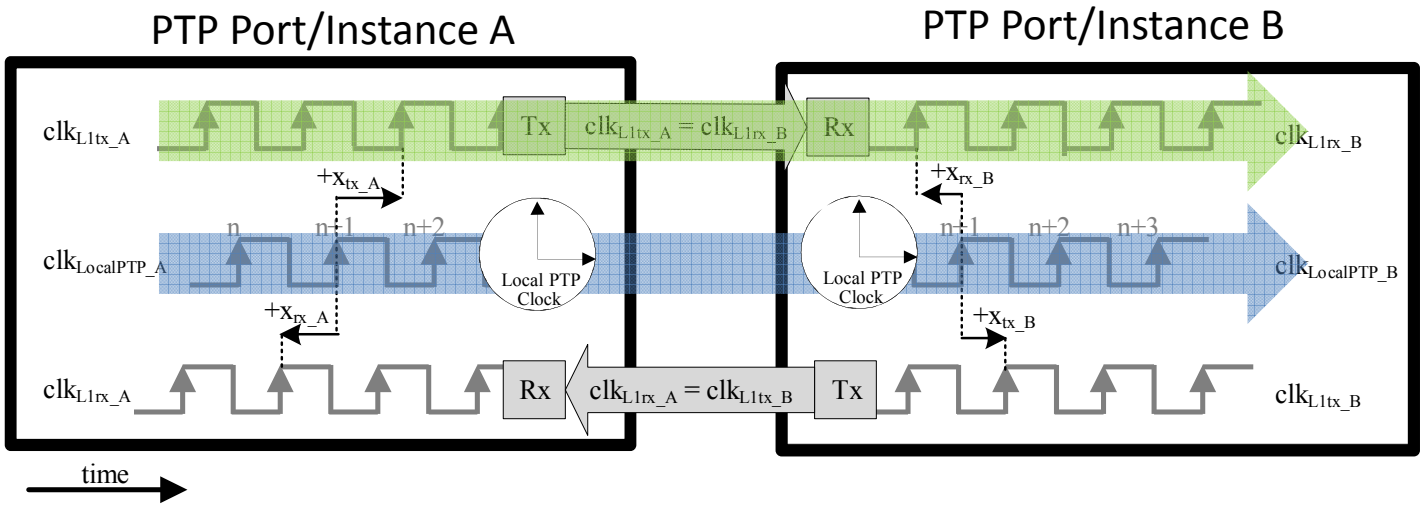


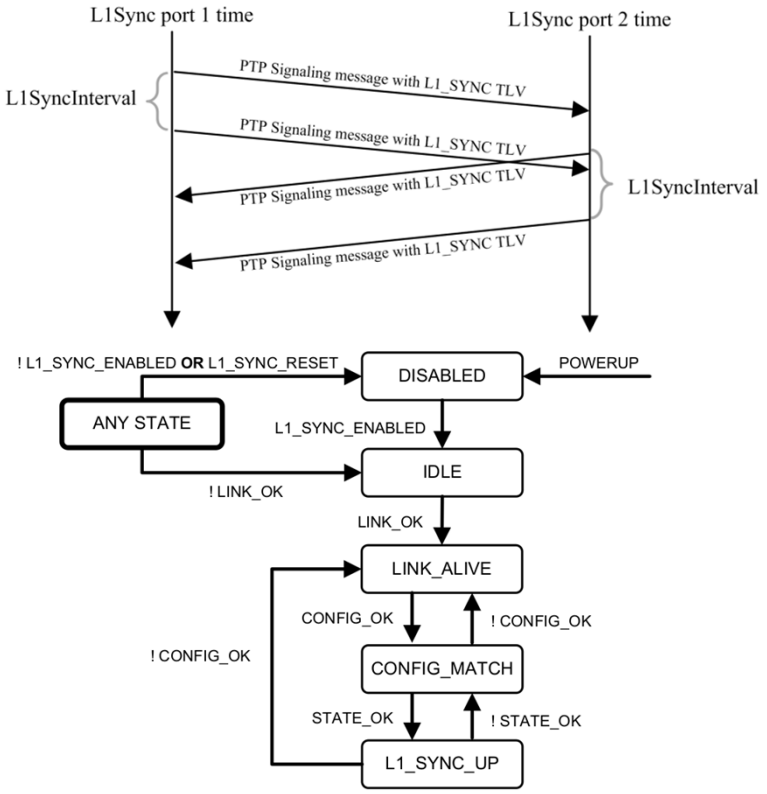
Transmit coherent port: x_{tx} = constant, so clk_{L1tx}= $clk_{LocalPTP}$

Receive coherent port : x_{rx} = constant, so clk_{L1rx}= $clk_{LocalPTP}$

Congruent port : flow of L1 syntonization and PTP synchronization are the same

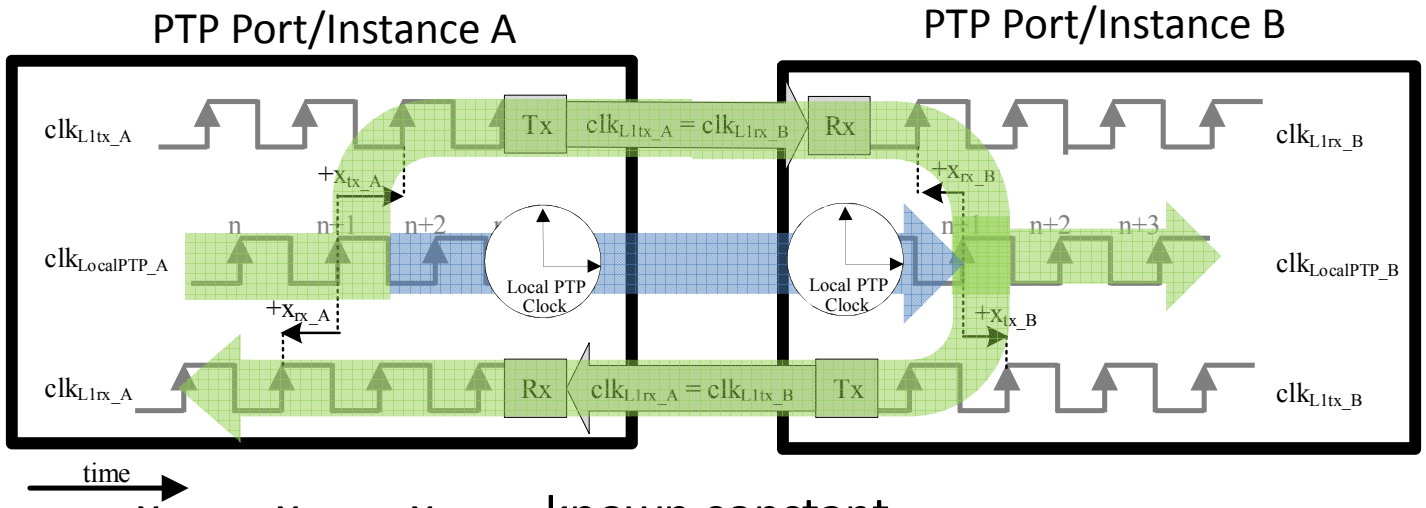
L1 synchronization enhancements (L1Sync)

- **Data sets:** storing config & status of the L1-PTP relationship (congruent, coherent)
- **L1_SYNC TLVs:**
  - Detection of L1Sync-supporting PTP Ports
  - Exchange of config/status/parameters
- **FSM:** control of establishing of the required PTP-L1 relationship
- **Know PTP-L1 relationship:** allows correction of timestamp with phase measurement



L1Sync in High Accuracy Default PTP Profile

- Requirement for L1Sync PTP Port to be: - transmit and receive coherent
  - congruent



$x_{tx\_A} = x_{rx\_B} = x_{tx\_B}$ = known constant

x_{rx_A} = phase measured to enhance timestamp precision

Options required/prohibited by HA Profile

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- Calculation of the <delayAsymmetry> for certain media **[16.8]**
- Requirements of Q.3 **[Annex Q]**

Required and inactive by default:

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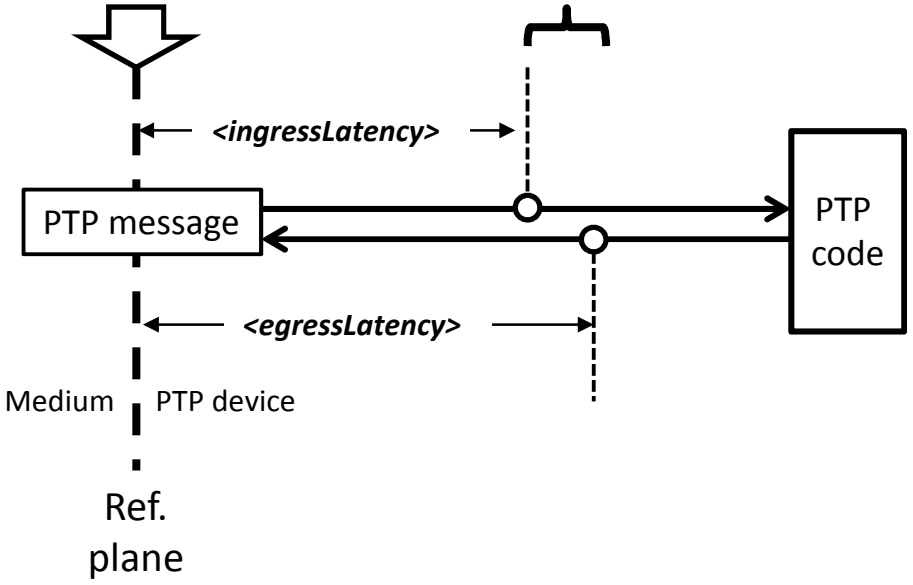
- masterOnly mode **[9.2.2.2 & 8.2.15.5.2]**

Prohibited:

- Isolation of PTP Instances **[16.5]**

Configurable correction of timestamps

- IEEE1588-2019 (and 2008) defines timestamping ref. plane and allows correction of timestamps for <ingressLatency> and <egressLatency>:
  - *<ingressTimestamp>=<ingressProvidedTimestamp> – <ingressLatency>*
  - *<egressTimestamp> = <egressProvidedTimestamp> + <egressLatency>*



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  - *<ingressTimestamp>=<ingressProvidedTimestamp> – <ingressLatency>*
  - *<egressTimestamp> = <egressProvidedTimestamp> + <egressLatency>*
- **This optional feature:**
  - Defines *timestampCorrectionPortDS* dataset to store the values of <egressLatency> & <egressLatency>
  - Mandates correction of timestamps with the provided values

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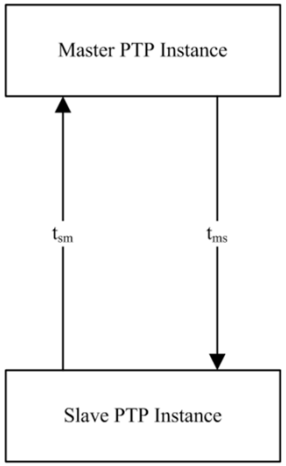
Calculation of <delayAsymmetry>

- IEEE1588-2019 (and 2008) provides calculation of <meanDelay> and allows correction of <meanDelay> for <delayAsymmetry>:

  $<meanDelay> = [(t_2 - t_1) + (t_4 - t_3)] / 2$

  $t_{ms} = <meanDelay> + <delayAsymmetry>$

  $t_{sm} = <meanDelay> - <delayAsymmetry>$



- **This optional feature:**
  - Defines <delayCoefficient> (α) to characterize asymmetry of applicable bidirectional media (e.g. bidirectional fiber)
  - Specifies <delayAsymmetry> calculation using <delayCoefficient> (α)

    <delayAsymmetry> = constantAsymmetry + [α/(α+2)]·(<meanDelay>)

  - Defines asymmetryCorrectionPortDS dataset for <delayCoefficient> & constantAsymmetry
  - Mandates correction of <meanDelay> with the calcualted <delayAsymmetry>

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Calibration

- Values of **<ingressLatency>, <egressLatency>, <delayCoefficient>** obtained using Calibration Procedures [Annex Q]
- [Q.3] defines requirements for PTP Instance in calibration procedures:
  1. Output signal, e.g. pulse-per-second (PPS)
  2. Optional features in 16.7 & 16.8 supported and enabled
  3. The value <meanDelay> exposed to the user
  4. Timestamps with precision sufficient for the intended accuracy of synchronization
  5. <egressProvidedTimestamp> and <ingressProvidedTimestamp> corrected for semi-static latency (e.g. bitslide, see Q.2 and P.4.2)
  6. Timestamping Clock is the Local PTP Clock

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External config. of PTP Port state & masterOnly

- Best Master Clock Algorithm (BMCA) defines the state of each PTP Port in BC/OC and synchronization hierarchy in the entire PTP Network
- **Mechanism for external config. of a PTP Instance's PTP Port state:**
  - Disables BMCA and affects all PTP Ports on a PTP Instance
  - Allows configuring the desired state of each PTP Port
  - Defines externalPortConfigurationPortDS dataset to store the desired state
  - Provides external configuration of synchronization hierarchy in the entire PTP network
- **masterOnly mode on PTP Port:**
  - Maintains operation of BMCA and provides configuration per PTP Port
  - Results in PTP Port ignoring Announce messages and defaulting to Master state
  - Prevents PTP Instance from "slaving" on particular PTP Ports (e.g. access ports)

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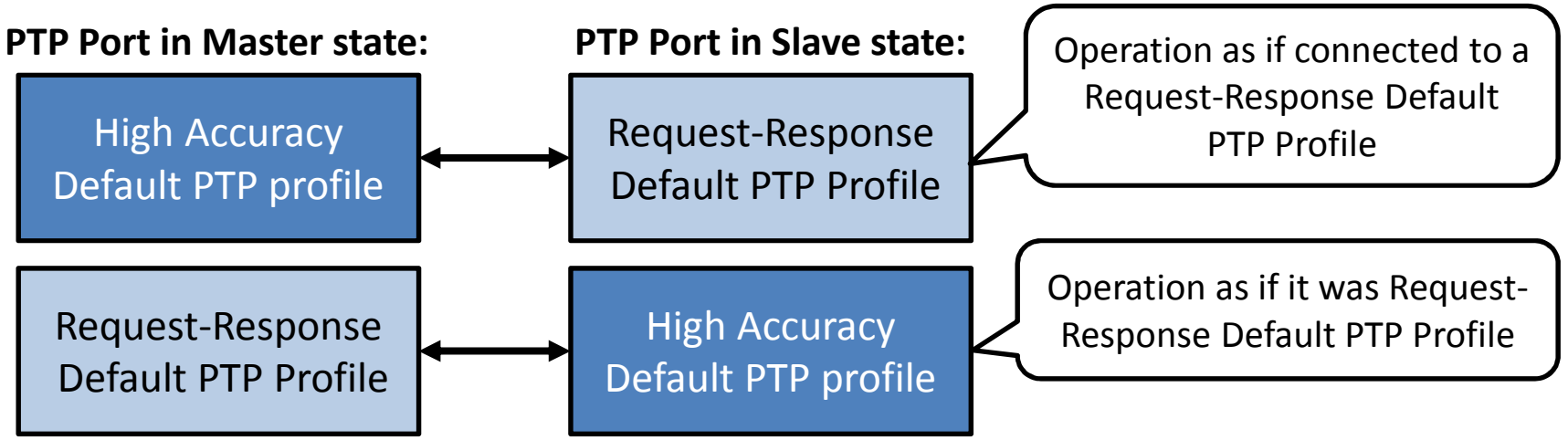
Inter-operation with Default PTP Profiles

- **High Accuracy Delay Request-Response Default PTP Profile**
  - Inter-operation with Delay Request-Response Default PTP Profile
  - Inter-operation with Peer-to-Peer Default PTP Profile, if peer-to-peer mechanism supported
  - No inter-operation with Transparent Clocks
  - No enhancements of synchronization performance



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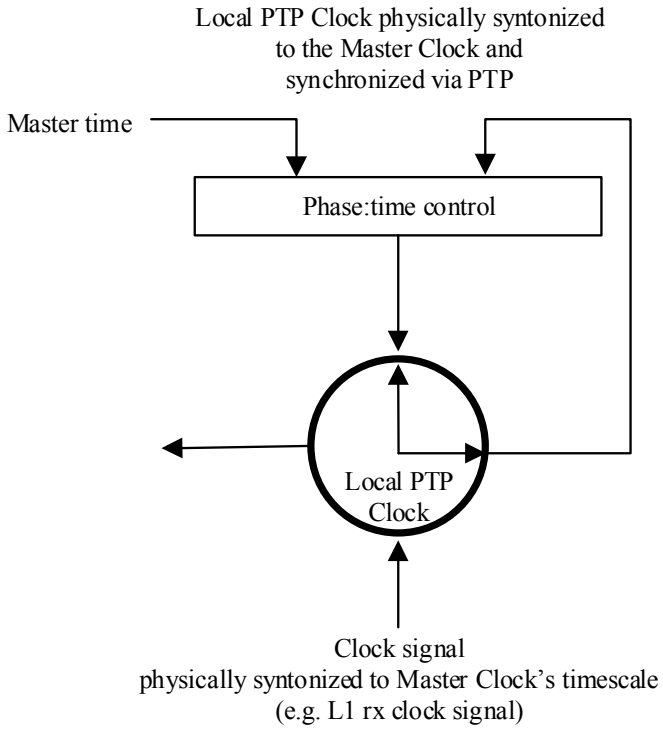
High Accuracy model of Local PTP Clock

High Accuracy Local PTP Clock in J.5.5 – highlights:

- Syntonization of Local PTP Clock
  - Physical to the Grandmaster, e.g. L1 clock signal
  - Independent from the PTP timing message exchange
- Synchronization of Local PTP Clock using PTP timing messages



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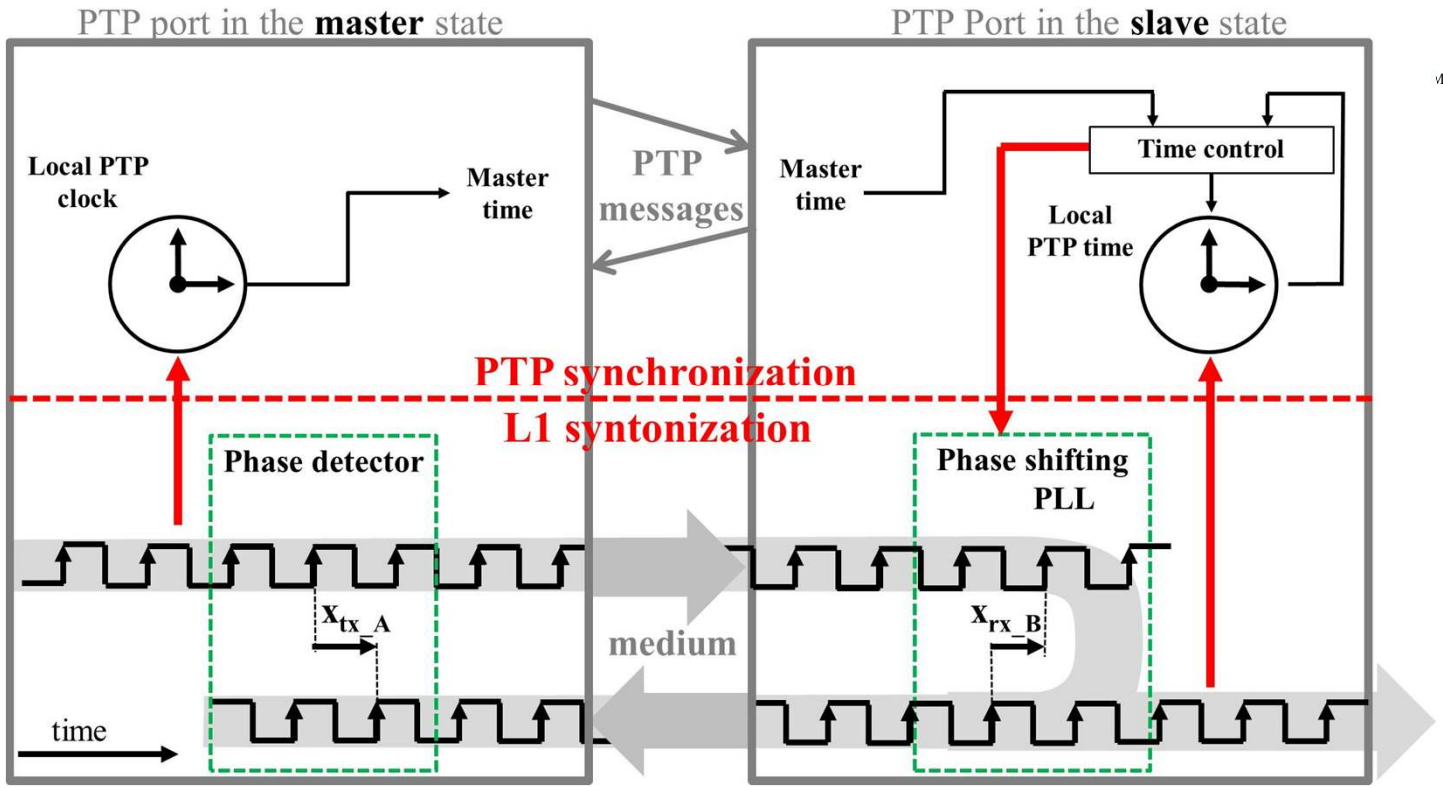

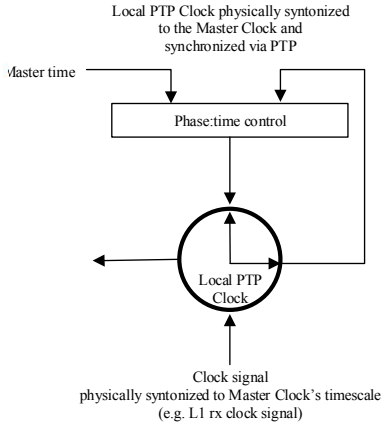

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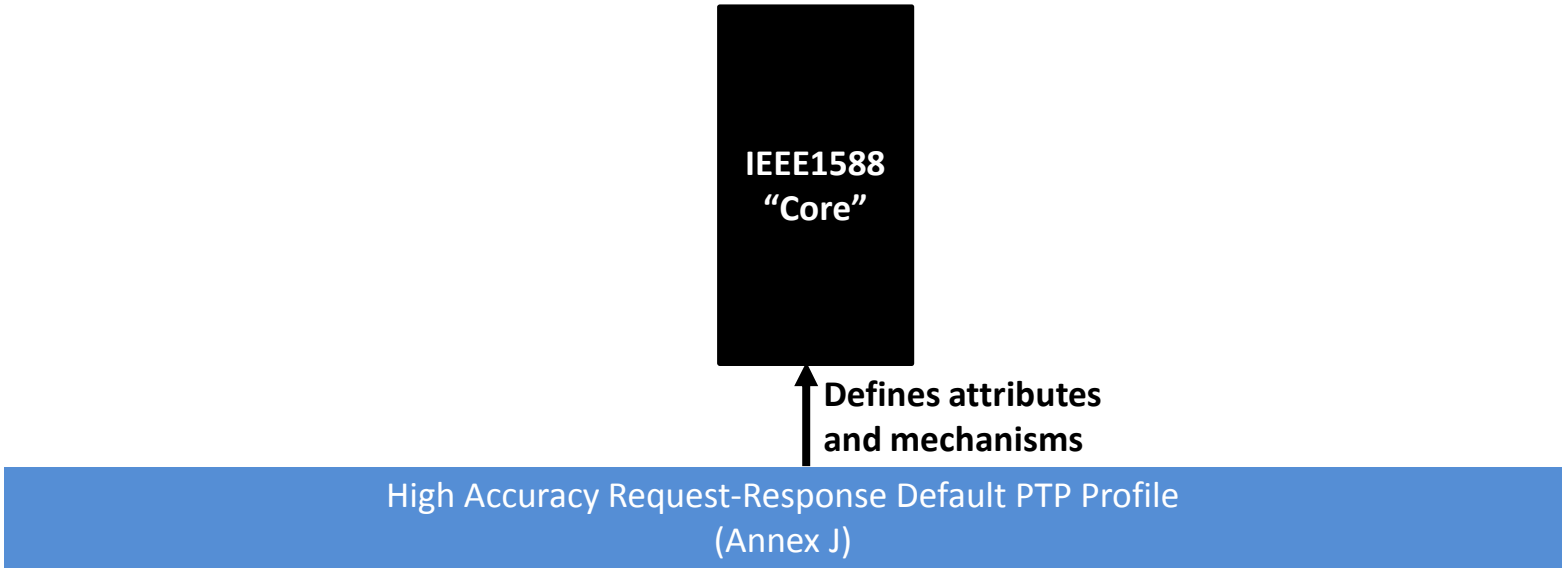
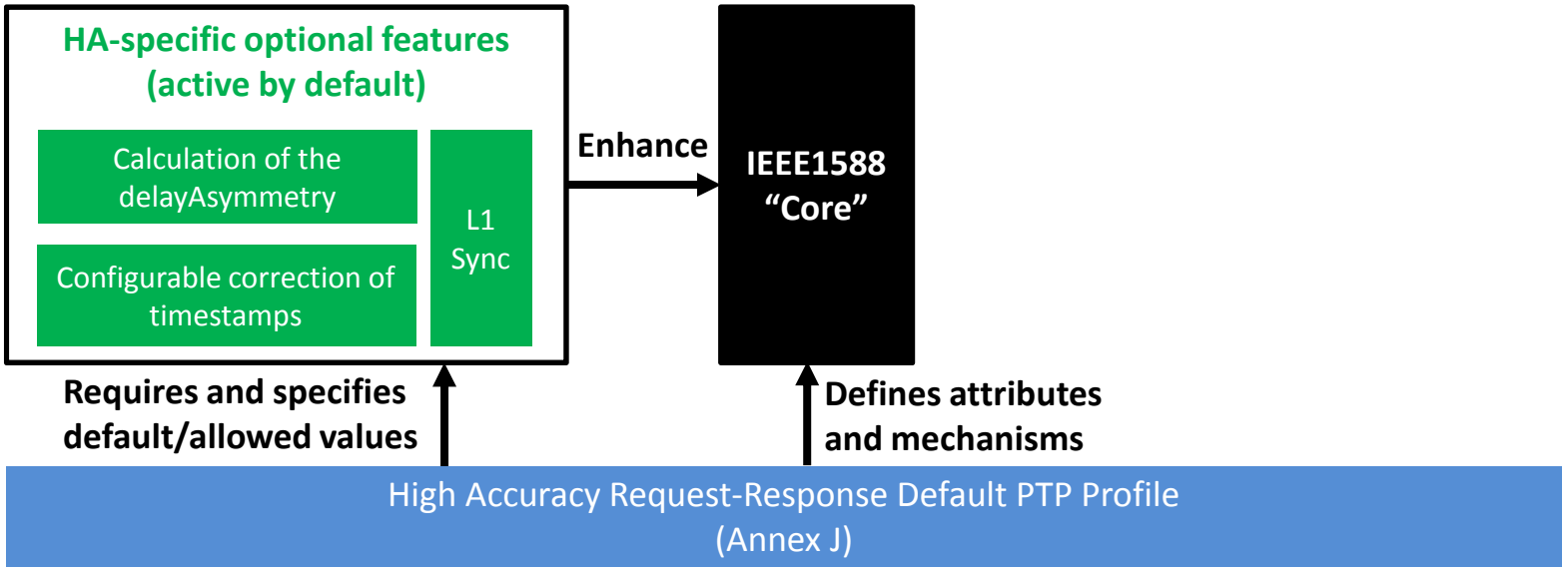

IEEE1588
"Core"
Defines attributes
and mechanisms
High Accuracy Request-Response Default PTP Profile
(Annex J)

Summary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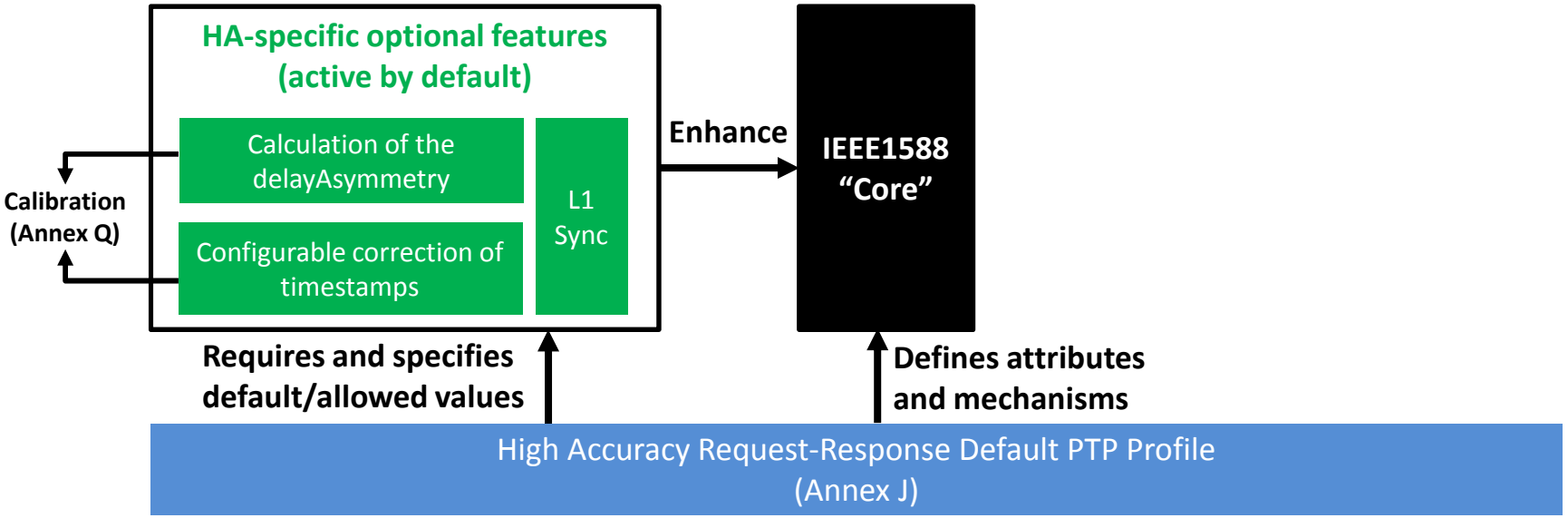
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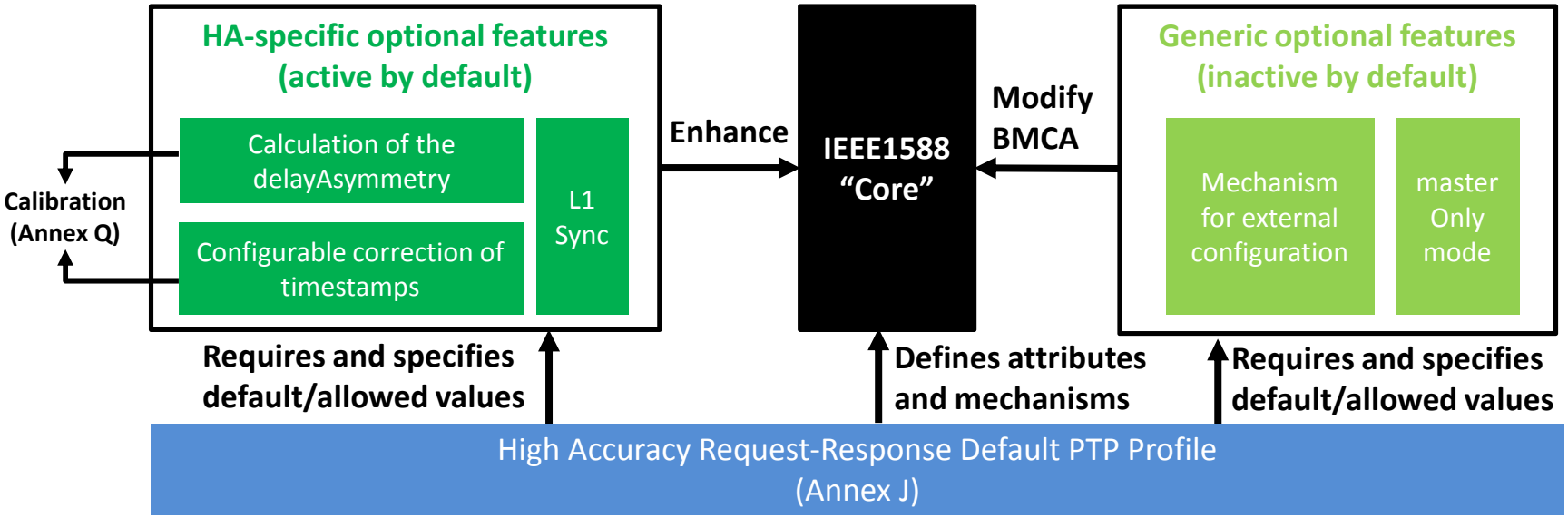
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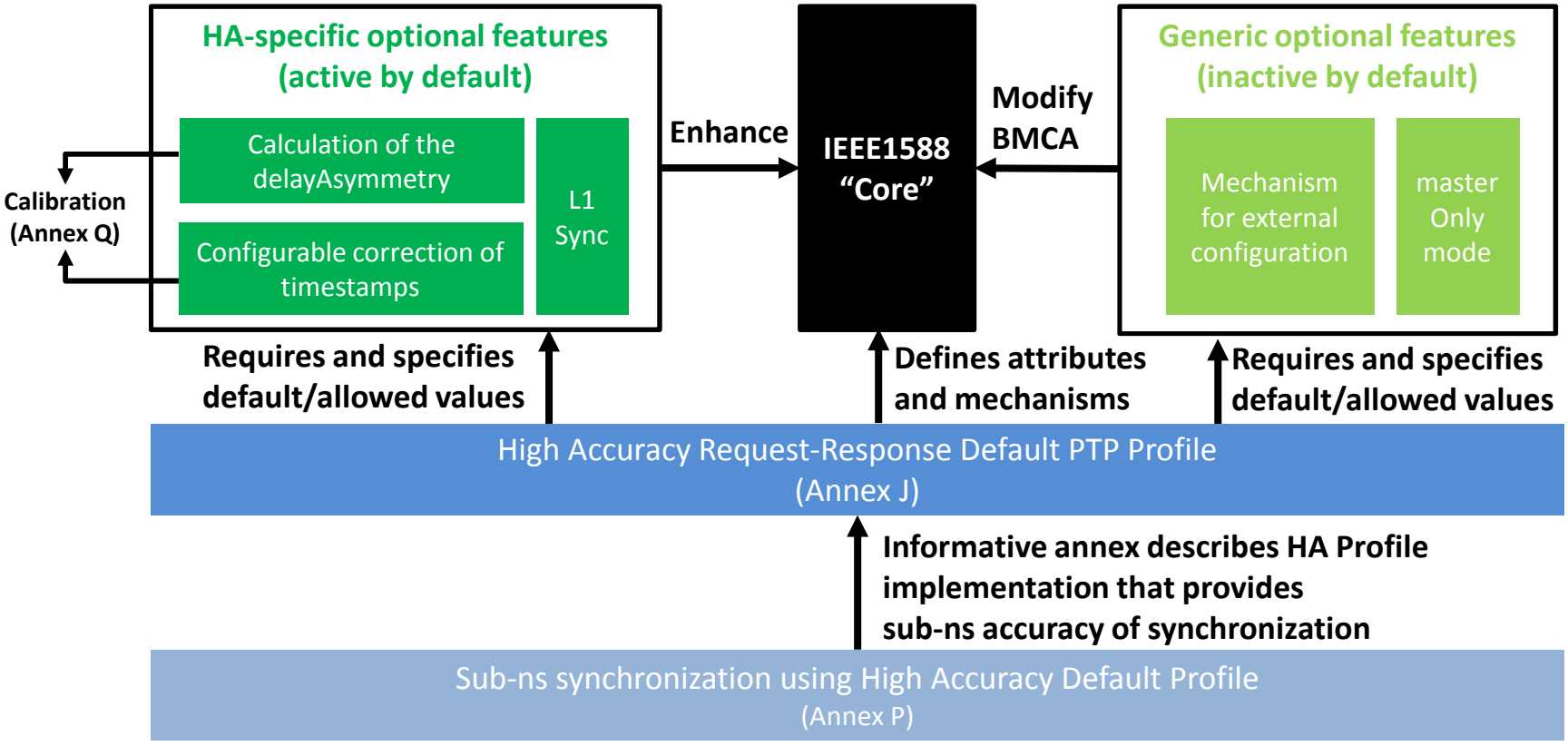
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High Accuracy Request-Response Default PTP Profile
(Annex J)
Informative annex describes HA Profile implementation that provides sub-ns accuracy of synchronization
Sub-ns synchronization using High Accuracy Default Profile
(Annex P)

Summary

HA-specific optional features (active by default)

Calculation of the delayAsymmetry

Configurable correction of timestamps

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Calibration (Annex Q)

Enhance

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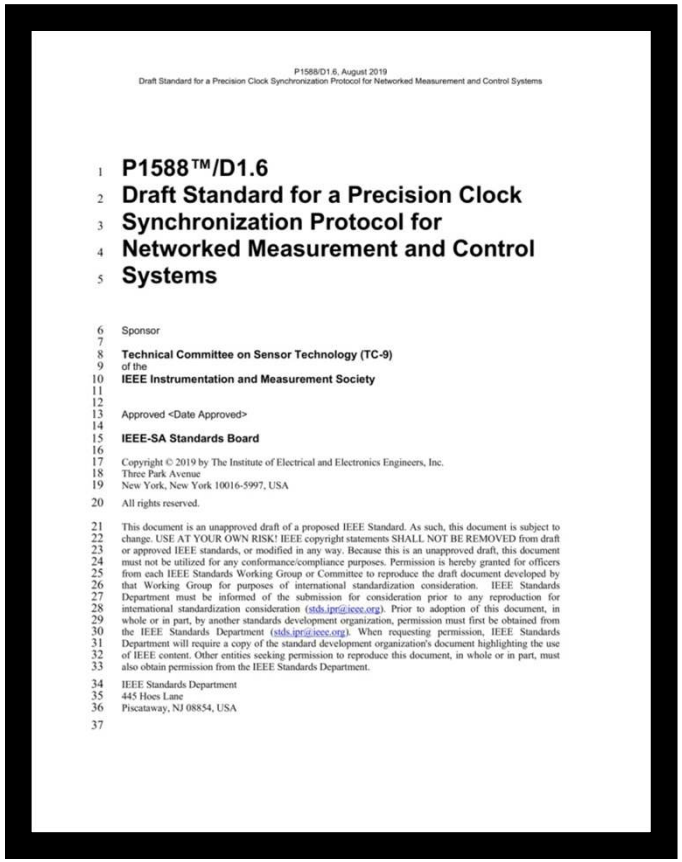
High Accuracy Request-Response Default PTP Profile (Annex J)

Informative annex describes HA Profile implementation that provides sub-ns accuracy of synchronization

Sub-ns synchronization using High Accuracy Default Profile (Annex P)

Backup slides

PTP Profiles and Optional Features



P1588/D1.6, August 2019
Draft Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems

P1588™/D1.6
Draft Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems

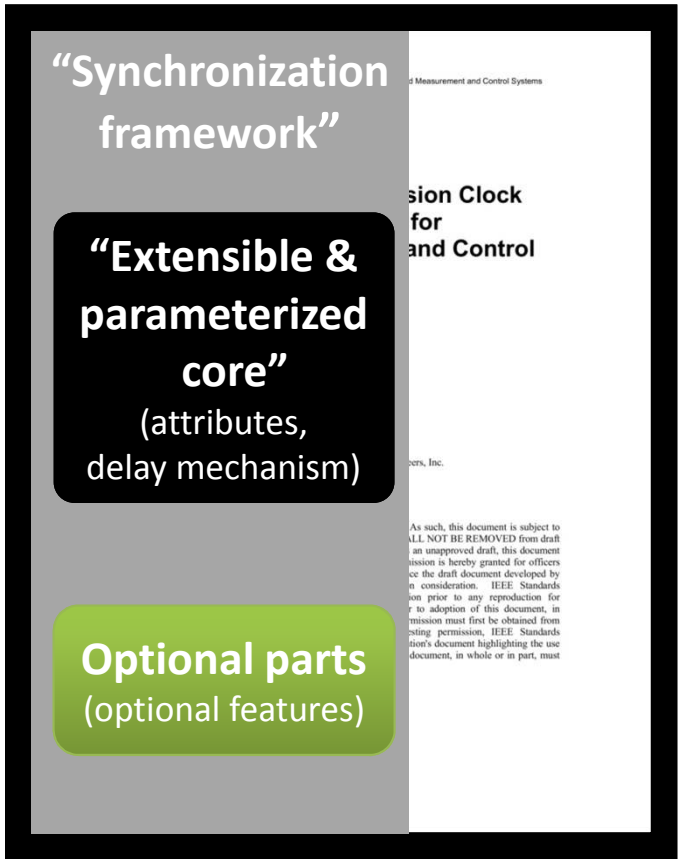
Sponsor

Technical Committee on Sensor Technology (TC-9)
of the
IEEE Instrumentation and Measurement Society

Approved <Date Approved>

IEEE-SA Standards Board

PTP Profiles and Optional Features



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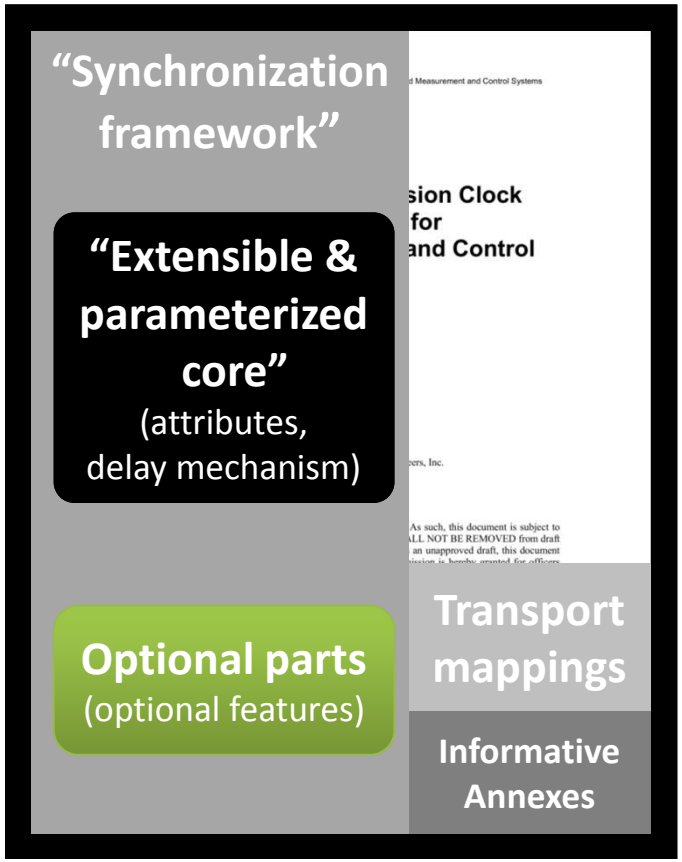

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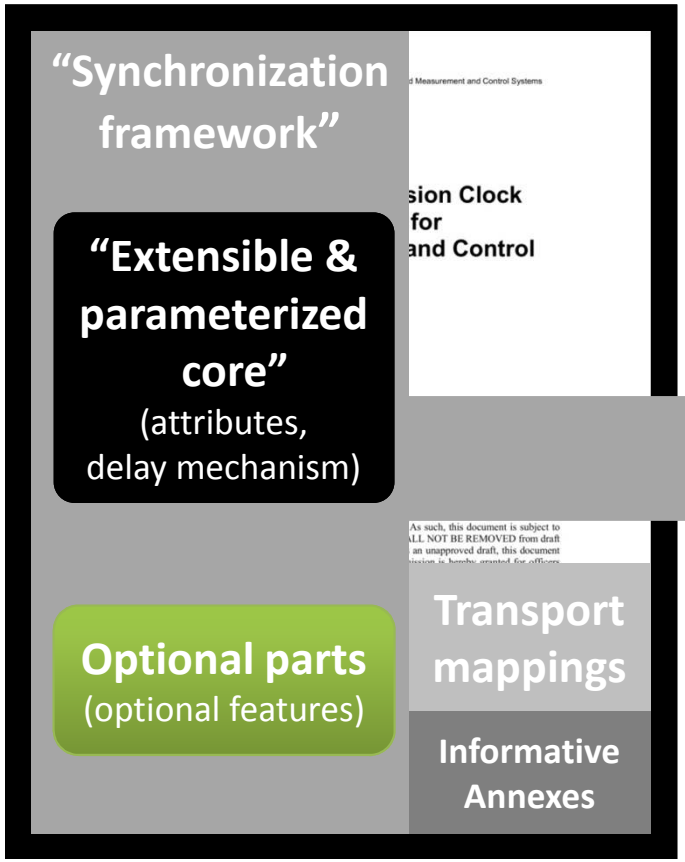

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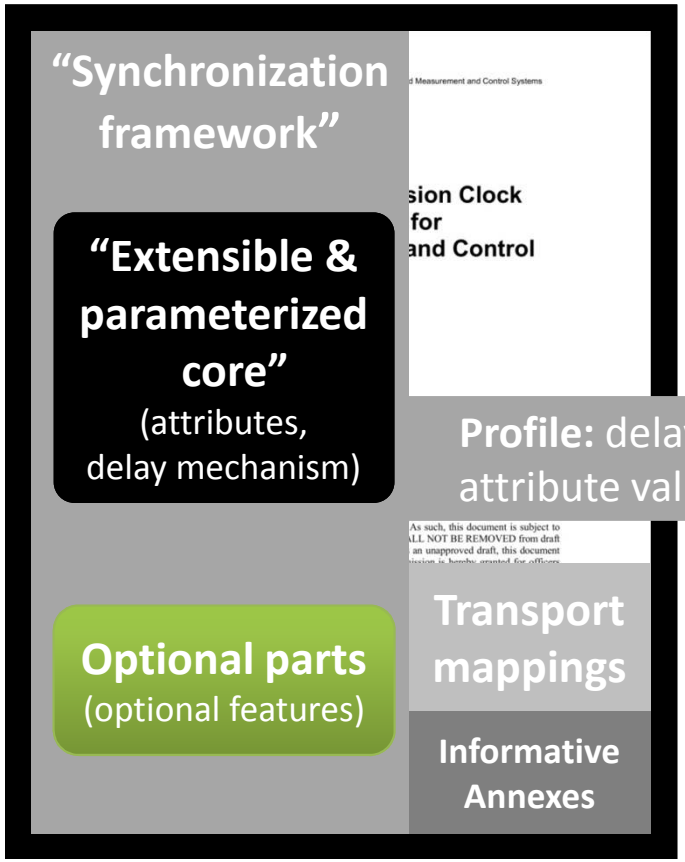
PTP Applications

Power

PTP Profiles and Optional Features



Profile: delay mechanism, attribute values & options

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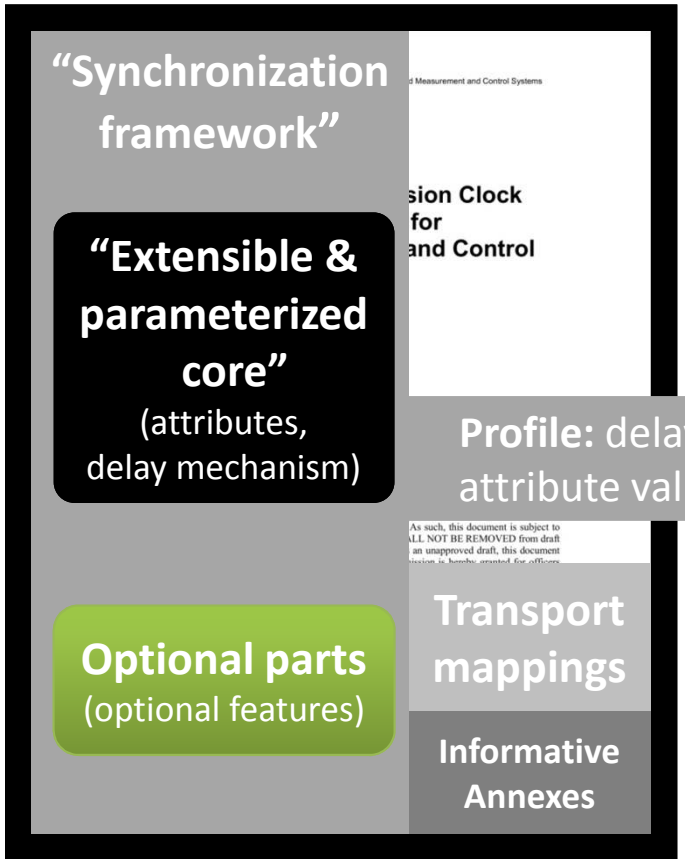
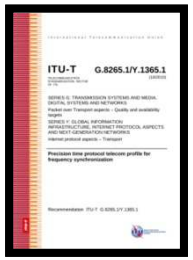
PTP Profiles and Optional Features





ITU-T Profiles

Profile: delay mechanism, attribute values & options

IEEE/IEC Profiles

Telecom

PTP Applications

Power

PTP Profiles and Optional Features