Multiple Timescale Feature for 802.1ASbt

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IEEE 802.1 TSN TG
2014.03.17

Outline

❑Introduction

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Introduction - 1

❑ One of the 802.1AS enhancements included in 802.1ASbt is the support of multiple timescales

❑ The feature, and the reasons it is needed, are described in detail in [1] – [4]

❑ Industrial applications require multiple timescales

- Universal Time (time of day) – transported to entire network, with $\pm100~\mu s$ accuracy over 128 or fewer hops [4]

- Working Clock (for synchronized control applications) – smaller area, with $\pm1~\mu s$ accuracy over 64 or fewer hops and ±100 ns accuracy over 8 or fewer hops [4]

❑ Each time-aware system must support universal time and at most one working clock

Introduction - 2

❏ While several possible approaches for supporting this feature have been described, it was decided that the approach using multiple time domains would be used

▪ The parameters and attributes could be different in each domain

❏ Since each time-aware system must support universal time and at most one working clock, each node would need to support at most two domains

▪ This is included in the latest 802.1ASbt assumptions in Annex Z [5]

❏ The present contribution provides a more detailed description of the assumptions for this feature, and outlines the changes/additions needed in 802.1ASbt for this feature

▪ It was felt best to first present the changes/additions for 802.1ASbt to the TSN TG before adding them to the draft

▪ Note that this material is preliminary, and for some items it is indicated that additional work or decisions are needed; it is expected that additional material or modifications to the material here may be needed as the draft is updated

Assumptions – 1

❑ Each time-aware system will support at most two domains

  ▪ Each time-aware system shall support at least one domain

❑ If a time-aware system supports only one domain, the default domain number shall be zero

  ▪ This is the default case, and corresponds to gPTP Gen 1

  ▪ A user can change the domain number if desired

❑ If a time-aware system supports two domains, then the domain numbers may have any integer value in the range 0 to 127

  ▪ The domain numbers may both be nonzero

    • In this case, if a time-aware system, A, for which both domain numbers are nonzero is connected to a time-aware system, B, for which one of the domain numbers is zero, the domains of A will not interact with domain zero of B

❑ We would like multiple domains to be supported for all 802.1AS transports if possible, but at least for full duplex 802.3 and 802.11 as these transports are expected to be used in industrial applications

Assumptions - 2

❑ The links for the applications that will use this feature are short enough in length that, relative to the worst-case frequency offset expected between grandmasters of the two domains, the mean propagation delay can be assumed to be approximately the same in all domains

- Assuming the grandmasters meet the 802.1AS frequency accuracy requirement of ±100 ppm (B.1.1 of 802.1AS-2011), two grandmaster may differ in frequency by at most 200 ppm = 2×10^{-4}

- Assuming a link delay on the order of 5 ns/m, the mean propagation delay for a 1 km link is (1000 m)(5 ns/m) = 5 μs

- This means that link delays measured using timestamps relative to two different GMs would differ by at most $(2 \times 10^{-4})(5 \ \mu s) = 10^{-3} \ \mu s$ = 1 ns

- Links in industrial applications are expected to be shorter than 1 km

❑ The above means that the peer delay mechanism, used for measuring mean propagation delay, can be domain-independent

- Note also that the neighborRateRatio is measured using local clocks and is unaffected by any grandmaster frequency offset

Assumptions – 3

❑ A mechanism will be included in 802.1ASbt that will enable a time-aware system to determine what domains its neighbors (i.e., the time-aware systems at the other ends of each attached link) support

- This is analogous to the feature in 802.1AS-2011 that uses the peer delay mechanism to determine if a neighboring time-aware system is asCapable (this is used only for full duplex 802.3 links, as other transports supported by 802.1AS-2011 do not use the peer delay mechanism)

- With this knowledge, a node will send messages related to synchronization transport (e.g., Sync) and best master selection (i.e., Announce), for a domain, only to nodes that support that domain

- However, information that is domain-independent (e.g., peer delay messages for full-duplex 802.3 links) will be sent regardless of which domain(s) the neighbor time-aware system (i.e., the system at the other end of the link attached to the sending port) supports)

  - Note that, for this information to be sent, the neighbor time-aware system must be asCapable

Assumptions – 4

❑ For information that is domain-independent, we need to decide how to handle the domainNumber field

❑ Possibilities:

- Always use domain number 0 on transmission, and ignore domain number on reception

- Reserve a domain number for this use (e.g., 127); use on transmission and ignore on reception

- Use the lowest domain number that the time-aware system supports on transmission, and ignore on reception

❑ Universal Time will typically use the PTP timescale

- However, Working Clocks need not use the PTP timescale

- The ARB timescale of IEEE 1588 (see 7.2.1 of IEEE 1588 – 2008) will be allowed, in addition to the PTP timescale

- Each domain will use either the PTP timescale or the ARB timescale

- Note that in IEEE 1588 – 2008, some clockClasses are specific to the PTP or ARB epoch; however, this will not impact 802.1ASbt because 802.1AS does not explicitly call out or use these clockClasses (but they are not prohibited)

Changes/Additions to 802.1ASbt - 1

❑ Subclause 8.1 – gPTP domain

▪ Modify the text to indicate that:

- One domain shall be supported

- Two domains may be supported

- If one domain is supported, the default domain number shall be zero

- If two domains are supported, the default domain numbers shall be integers in the range 0 to 127

▪ Add text that gives a general description of how multiple-domain information is organized in the remainder of the document

- Unless otherwise specified in this standard, the operation of the protocol and the timescale in different domains are independent (this is also stated in IEEE 1588 – 2008)

- Unless otherwise stated, information in the remainder of the document is per domain

  – For example, it would be indicated in the description of the peer delay mechanism that this information and mechanism is domain independent

  – As indicated in the assumptions, we need to decide what to use for the domainNumber field for domain-independent information

Changes/Additions to 802.1ASbt - 2

❑ Subclause 8.2.1 – Introduction (of 8.2 Timescale)

- Add description of the ARB timescale (following 7.2.1 of IEEE 1588, which describes both the PTP and ARB timescales)

- Note that it will be necessary to go through 802.1AS and possibly add references to the ARB timescale in places where the PTP timescale is mentioned

- Indicate in 8.2.4 that the epoch can be the PTP or ARB epoch

❑ Subclause 8.2.3 – UTC Offset

- It must be indicated that currentUtcOffset shall not be used to compute UTC when the timescale is ARB (this was recently clarified by the P1588 Upkeep Subcommittee)

Changes/Additions to 802.1ASbt - 3

❏ Clause 9 – Application interfaces

- This clause describes a ClockSourceTimeInterface, which provides external time to a time-aware system, and four Clock Target interfaces, which provide time from a time-aware system to an application

- It needs to be decided whether domainNumber needs to be added to these interfaces

  - If these interfaces are considered to be implicitly associated with a domain, then domain number is not needed

  - If these interfaces are considered to be associated with the time-aware system as a whole, then domain number is needed

❏ Subclause 10.2.7 – PortSyncSyncReceive state machine

- It must be indicated that neighborRateRatio (see definition in 10.2.4.6 and state machine in Figure 10-4) is domain-independent

❏ Subclause 10.2.12 – ClockSlaveSync state machine

- It must be indicated that neighborPropDelay (see definition in 10.2.4.7 and state machine in Figure 10-9) is domain-independent

Changes/Additions to 802.1ASbt – 4

❑ Subclause 10.5.2.2.5 – domainNumber (field of common header)

- The subclause references 8.1 for information on domain number

- However, description is needed for the case of information that is not domain specific (e.g., peer delay messages in the case of full-duplex 802.3 transport)

❑ Subclause 10.5.4.2.2 – Message interval request TLV

- This TLV currently carries linkDelayInterval, timeSyncInterval, and announceInterval

  - The first is domain independent, and the latter two are domain-specific

  - We can handle this by having the domain number pertain only to the domain-specific information

  - Note also that the domain-specific information must pertain to a single domain, i.e., if it were desired to send an announceInterval for domain 0 and timeSyncInterval for domain 1, then two TLVs would be needed

    – Related to this, we must clarify that a single Signaling message can carry more than one TLV (this is allowed in 1588 – 2008)

    – If we use different TLVs for the domain-specific and domain-independent information, we need to change the AnnounceIntervalSetting state machine (SM) (10.3.14) and LinkDelaySyncIntervalSetting SM so they are consistent with this

Changes/Additions to 802.1ASbt - 5

❑ Subclause 11.1.2 – Propagation delay measurement

- This subclause must indicate that the mean propagation delay measurement is domain-independent

❑ Subclause 11.1.3 – Transport of time-synchronization information

- This subclause must indicate which information (i.e., neighborPropDelay, neighborRateRatio) is domain-independent

❑ Subclause 11.2.9 – MDTimestampReceive

- It is expected that the timestamp model for full-duplex 802.3 transport will be changed to correspond to 802.3bf and/or any new model introduced in the revision of IEEE 1588 that is underway; however, it is also expected that the model will still be based on the free-running LocalClock, and therefore will be domain-independent
  - The domain-independence must be indicated

❑ Subclause 11.2.12 – MD entity global variables

- All the variables except syncSequenceId are domain-independent; this must be indicated

Changes/Additions to 802.1ASbt - 6

❑Subclause 11.2.13 – MDSyncReceive state machine

▪It must be indicated that neighborPropDelay and neighborRateRatio (see definitions in 10.2.4.7 and 10.2.4.6) are domain-independent

❑Subclause 11.2.15 – MDPdelayReq state machine

▪It must be indicated that this subclause is domain-independent

❑Subclause 11.2.16 – MDPdelayResp state machine

▪It must be indicated that this subclause is domain-independent

❑Subclauses 11.2.15 and 11.2.16 – MDPdelayReq and MDPdelayResp state machines, respectively

▪The mechanism by which a time-aware system port determines what domains its neighbors support must be specified

▪It is proposed that this be done using the peer delay mechanism and a new supportedDomains TLV

▪This TLV will contain a list of domains that a peer delay responder supports

▪When a port receives Pdelay_Req, if it supports this feature it will attach this TLV to Pdelay_Resp_Follow_Up

Changes/Additions to 802.1ASbt - 7

❑ Subclause 11.3 – Message attributes

- It must be indicated which messages are domain-independent (i.e., Pdelay_Req, Pdelay_Resp, Pdelay_Resp_Follow_Up)
    - The various subclauses of 11.3 must be examined so that information that is domain-independent can be indicated as such

❑ Subclause 11.4.5 – Pdelay_Req message

- It must be indicated that this subclause is domain-independent

❑ Subclause 11.4.6 – Pdelay_Resp message

- It must be indicated that this subclause is domain-independent

❑ Subclause 11.4.7 – Pdelay_Resp_Follow_Up message

- It must be indicated that this subclause is domain-independent

❑ Subclause 11.5.2.2 – Pdelay_Req message transmission interval

- It must be indicated that this subclause is domain-independent

❑ Subclause 11.5.3 – allowedLostResponses

- It must be indicated that this subclause is domain-independent

Changes/Additions to 802.1ASbt - 8

❑Clause 12 – Media-dependent layer specification for IEEE 802.11 links

- The mechanism for a port attached to an 802.11 link to let its neighbor(s) know which domains it supports must be defined

- One possibility might be to attach the supportedDomains TLV to the Timing Measurement Action Frame and to the ACK

- The following should be investigated

  - Can 802.1AS define additional vendor-specific information (e.g., with a Type=1) that would signify the supportedDomains TLV?

  - Can this information be attached to ACK (currently the Timing Measurement Action Frame carries vendor-specific information with Type=0 (FollowUpInformation)?

- If the above is possible, it must be described, and respective processing of the information must be added to the master and slave state machines

  - If the above is not possible, alternative approaches must be examined, e.g., use of Signaling messages to carry the supportedDomains TLV

Changes/Additions to 802.1ASbt - 9

❑ Clause 12 – Media-dependent layer specification for IEEE 802.11 links

- The content of clause 12 must be examined, so that the various aspects can be indicated as domain-independent or domain-specific

- Essentially, the FollowUpInformation TLV and aspects related to this (e.g., use of its parameters in state machines, and related local variables, shared variables, and functions) are domain-specific, and other aspects are domain-independent

- Note that the timestamps T1, T2, T3, and T4, and the computation of neighborPropDelay and neighborRateRatio are domain-independent

Changes/Additions to 802.1ASbt - 10

❑ Clause 13 – Media-dependent layer specification for interface to IEEE 802.3 Ethernet passive optical network links

▪ In EPON transport, the TIMESYNC message, transported using the organization-specific slow protocol, carries the correspondence between grandmaster time and MPCP counter. It is necessary to:

- Add the domain number to the TIMESYNC message; note that now the TIMESYNC message is per domain (subclause 13.3)

- Indicate which fields of the TIMESYNC message are domain-independent, and which are domain-specific (subclause 13.3)

- Add the domain number to the OSSPDU.request, and indicate which parameters are domain-independent and which are domain-specific (subclause 13.6.1)

- Add the domain number to the OSSPDU.indication, and indicate which parameters are domain-independent and which are domain-specific (subclause 13.6.2)

- Indicate which aspects of the requestor state machine are domain-independent and which are domain-specific (subclause (13.8)

- Indicate which aspects of the responder state machine are domain-independent and which are domain-specific (subclause (13.9)

- Indicate that the TIMESYNC message transmission interval is per domain (subclause 13.9.1)

Changes/Additions to 802.1ASbt – 11

❑Clause 13 – Media-dependent layer specification for interface to IEEE 802.3 Ethernet passive optical network links

- The mechanism for a port attached to an 802.3 EPON link to let its neighbor(s) know which domains it supports must be defined

- The supportedDomains TLV cannot simply be attached to the TIMESYNC message, because that message is domain-specific

- Possible solutions are:

  - Carry the supportedDomains TLV in a Signaling message

  - Carry the supportedDomains TLV in a new message carried using the organization-specific slow protocol

  - Whatever solution is used, the relevant messages and state machines must be described (much of the material from clause 11 could be re-used)

Changes/Additions to 802.1ASbt - 12

❑ Clause 14 – Timing and synchronization management

- After clauses 1 – 13 and Annex E are updated for multiple-domain support, each managed object of clause 14 must be indicated as domain-specific (i.e., one instance per domain) or domain-independent

  - It may be necessary to split the Port Parameter data set and Port Parameter statistics data set into domain-independent and domain-specific portions

  - Only the domain-specific portion would have multiple instances (one instance per domain)

  - Note that such a splitting would not cause non-compliance with IEEE 1588, because 1588 requires that there be management, but not the specific management scheme of 1588

  - Datasets other than the Port Parameter and Port Parameter statistics data sets are per domain (i.e., domain-specific)

❑ Clause 15 – Managed object definitions

- The MIB must be generalized to allow for multiple domains, in accordance with the changes to clause 14

Changes/Additions to 802.1ASbt – 13

❑ Annex A – PICS Proforma

- Appropriate PICS entries related to multiple domain support must be added

- The feature is optional, but if it is implemented it shall be implemented as specified

❑ Annex B – Performance requirements

- It must be indicated that if multiple domains are present, the requirements of Annex B apply to all the domains

Changes/Additions to 802.1ASbt – 14

❑ Annex E – Media-dependent layer specification for CSN network (note that it has been agreed to make Annex E a numbered clause, following clause 15)

- As with other transports, the best master selection and time synchronization transport aspects are domain-specific

- The path delay measurement and any neighborRateRatio measurement are domain-independent

- If there is no network reference clock, the CSN uses the peer delay mechanism for path delay and neighborRateRatio measurement

  - In this case, the operation is the same as for full-duplex 802.3, and the domain-independent and domain-specific aspects are the same as in that case

- If there is a network reference clock, neighborPropDelay and neighborRateRatio are not computed

  - The computations described are domain-specific, except for the neighborRateRatio and neighborPropDelay fields of the CSN TLV; these fields are domain-independent, and pertain the link attached to the CSN ingress port (i.e., not to the CSN itself)

- It is necessary to indicate which aspects of Annex E are domain-specific and which are domain-independent

Changes/Additions to 802.1ASbt – 15

❑Annex F – PTP profile included in this standard

- ▪In F.2, item (a), it must be indicated that there may be two domains, but at least one is required (and if there is only one, the default domain number is 0).

- ▪In F.3, item (c), it must be indicated that the peer delay mechanism is domain-independent

- ▪In F.3, item (f), it must be indicated that the neighborRateRatio measurement is domain-independent

References – 1

[1] Franz-Josef Goetz, Clemens Hoga, and Karl Weber, *Dual Time Scale in Factory & Energy Automation,* v1.02, White Paper about Industrial Requirements and Concepts @ Time Synchronization, July 16, 2012.

[2] Franz-Josef Goetz, *Two Time Scales @ Industry*, Presentation to IEEE 802.1 AVB Meeting, Waikoloa, March 11, 2012.

[3] Franz-Josef Goetz, *Which Mechanism for Two Time Scales @ Industry*, Presentation to IEEE 802.1 AVB Meeting, San Diego, July 15, 2012.

[4] Franz-Josef Goetz, *Mechanism to support Multiple Sync Domains @ IEEE 802.1 AS Gen 2*, Presentation to IEEE 802.1 TSN Meeting, San Antonio, November 11, 2012.

[5] Latest Draft IEEE 802.1ASbt/D0.3, January 15, 2014.