Annex J (informative)

Media-dependent layer specification for CSN Network

J.1. Overview

Accurate time is distributed throughout an 802.1AS domain through time measurements between adjacent time-aware bridges or end stations in a bridged local area network. Time is communicated from the root of the clock spanning tree (i.e. the grand master, assuming the root is grandmaster-capable) toward the leaves of the tree (i.e. through a leaf-facing 'master' port to some number of root-facing 'slave' ports) through measurements made across the links connecting the devices. While the semantics of time transfer are consistent across the time-aware bridged LAN, the method for communicating time from a master station to its immediate downstream link partner varies depending on the type of link interconnecting the two time-aware systems.

This appendix specifies the protocol that provides accurate clock synchronization across the links of a Coordinated Shared Network (CSN) that are part of a bridged LAN.

J.2. Coordinated shared network characteristics

A Coordinated Shared Network (CSN) is a contention-free, QoS-able, time-division multiplexed-access, network. One of the nodes of the CSN acts as the network coordinator node, granting transmission opportunities to the other nodes of the network.

NOTE - In this annex, the term node is used to refer to a CSN node (i.e., it does not refer to a time-aware bridge or end station).

A CSN supports two types of transmission: unicast transmission for point-to-point (node-to-node) transmission and broadcast transmission for point-to-multipoint (node-to-all-other-nodes) transmission. Each node-to-node link has its own bandwidth characteristics, which can change over time as a result of the periodic ranging of the link. The broadcast transmission characteristics are the lowest common characteristics of all the links of the network.

A CSN network is physically a shared network, in that a CSN node has a single physical port connected to the half-duplex medium, but is also a logically fully-connected one-hop mesh network, in that every node can transmit to every other node using its own profile over the shared medium.

Figure J - 1 illustrates a CSN network acting as a backbone for 802.3 time-aware systems.

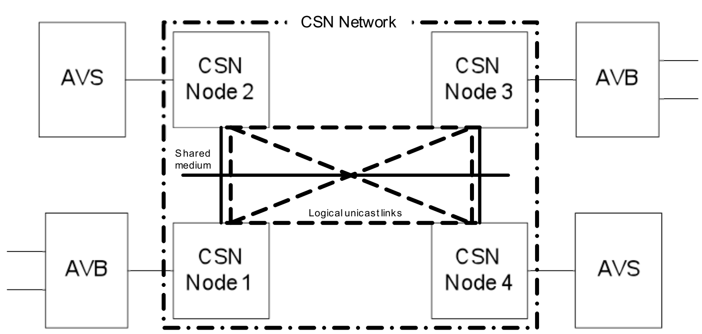

Figure J - 1 - Example of CSN Backbone in an AVB LAN

J.3. Layering for CSN links

A PortSync entity and an MD entity are associated with each CSN logical port (node-to-node link) as illustrated in Figure J-2. The MD entity is the same MD entity described in Clause 11. It translates media-independent primitives to media-dependent primitives as necessary for communicating time over the CSN links.

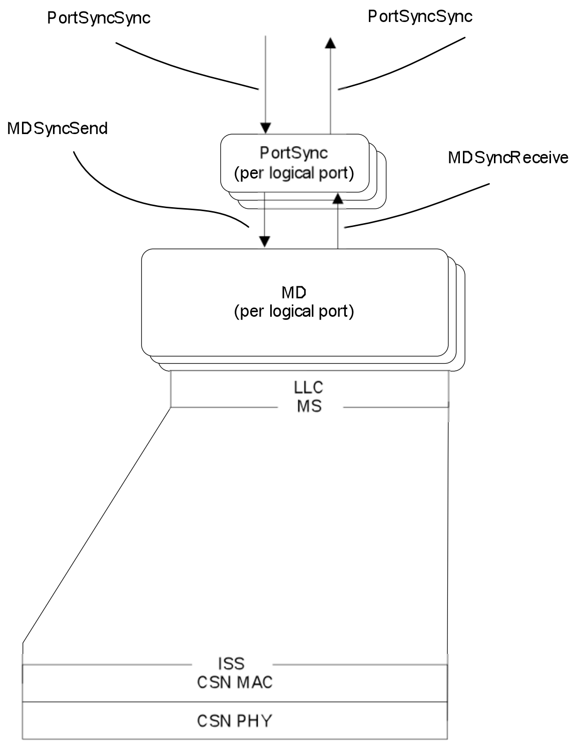

Figure J - 2 - MAC dependent and lower entities in CSN nodes

J.4. *Path delay measurement over a CSN backbone*

The Path Delay over a CSN backbone must be calculated for the following path types: (1) between the upstream 802.3 time-aware bridge and the ingress CSN node, (2) between the ingress and egress CSN nodes, and (3) between the egress CSN node and the downstream 802.3 time-aware bridge or end station,

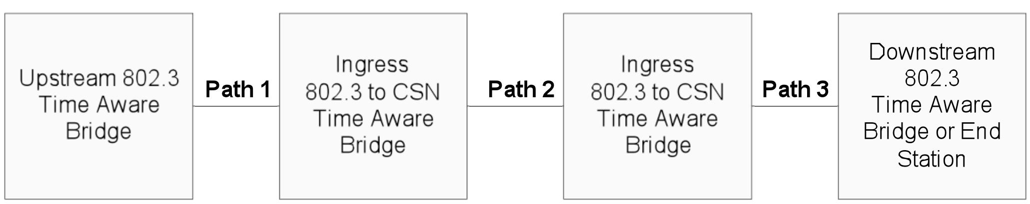

Figure J - 3 – Path types over CSN as 802.1AS backbone

To maintain the synchronization, residence time on each node and the propagation delay between nodes is measured, requiring precise time stamping on both Ethernet and CSN ingress and egress ports as illustrated in Figure J - 4 (“Path i” in the figure refers to the paths enumerated in Figure J - 3.

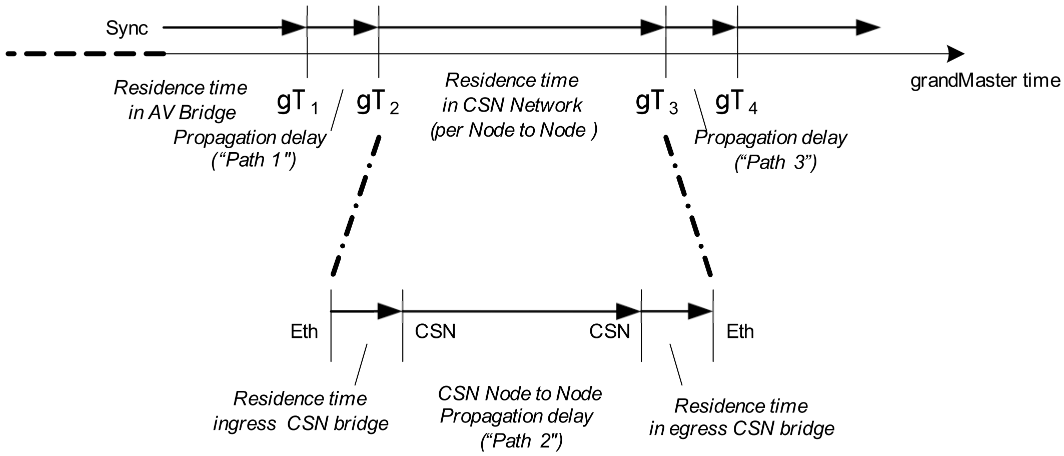

Figure J - 4 - Propagation delay and residence time over a CSN Backbone

J.4.1 Path delay measurement at the CSN boundaries

At the boundaries of the CSN, a CSN node features a full-duplex 802.3 port. Therefore, the path delay measurement between a time-aware bridge or end station and a CSN node uses the protocol, messages, and state machines described in Clause 11.2.12 and 11.2.13 for full-duplex 802.3 point-to-point links.

The CSN node both terminates Pdelay_Req messages sent by the time-aware systems (bridge or end station) and generates Pdelay_Req messages to the time-aware systems to measure the path delays between the time-aware system and the CSN node, as illustrated in Figure J - 5

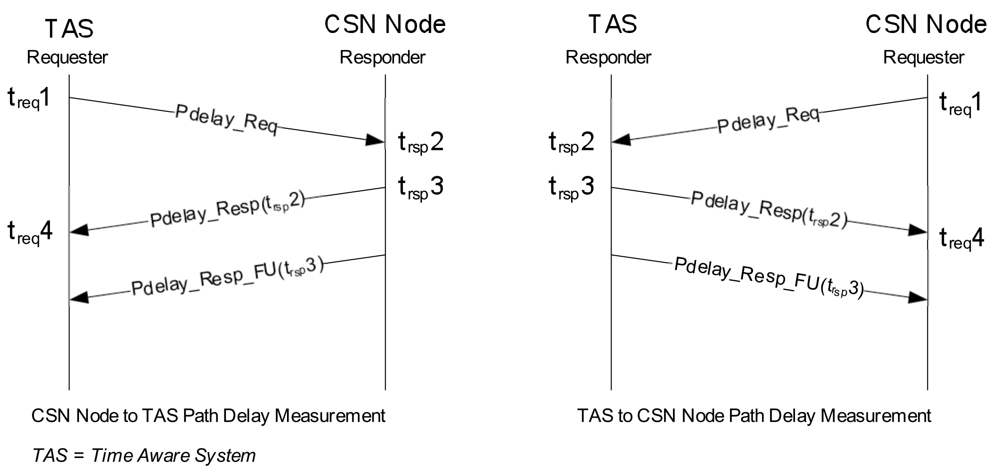

Figure J - 5 - Path delay measurements at the CSN boundaries

The computation of the neighborRateRatio and neighborPropDelay between the time-aware bridge or end station and the CSN node are described in 11.2.12.2.3 and 11.2.12.2.4, respectively. Any scheme that uses the timestamps at the requestor and the information conveyed in the successive Pdelay_Resp and Pdelay_Resp_Follow_Up messages is acceptable, as long as the performance requirements of Annex B are met. As one example, the neighborRateRatio is computed as the ratio between a time interval measured by the local clock of the responder and its associated time interval measured by the local clock of the requester, using a set of received Pdelay_Resp and Pdelay_Resp_Follow_Up messages and a second set of received Pdelay_Resp and Pdelay_Resp_Follow_Up messages some number of Pdelay_Req message transmission intervals later, i.e.,

$$\frac{(t_{rsp}3)_N - (t_{rsp}3)_0}{(t_{req}4)_N - (t_{req}4)_0} \qquad \text{(J-1)}$$

where $(t_{rsp}3)_k$ is the time relative to the local clock of the responder that the k^{th} Pdelay_Resp message is sent, $(t_{req}4)_k$ is the time relative to the local clock of the requestor that the kth Pdelay_Resp message is received, N is the number of Pdelay_Req message transmission intervals separating the first set of received Pdelay_Resp and Pdelay_Resp_Follow_Up messages and the second set, and the successive sets of received Pdelay_Resp and Pdelay_Resp_Follow_Up messages are indexed from 0 to *N* with the first set indexed 0. The neighborPropDelay between the time-aware system and the CSN node is computed as

$$\frac{(t_{req}4 - t_{req}1) * r - (t_{rsp}3 - t_{rsp}2)}{2} \quad \text{(J-2)}$$

where r is equal to neighborRateRatio, $t_{req}1$ is the time relative to the local clock of the requestor that the Pdelay_Req message for this message exchange is sent, $t_{rsp}2$ is the time relative to the local clock of the responder that the Pdelay_Req message for this message exchange is received, $t_{rsp}3$ is the time relative to the local clock of the responder that the Pdelay_Resp message for this message exchange is sent, and $t_{req}4$ is the time relative to the local clock of the requestor that the Pdelay_Resp message for this message exchange is received.

J.4.2 Path delay measurement between CSN nodes

The path delay between the two nodes of the CSN is the propagation delay (of a single link/wire, not end-to-end path) for the logical link that connects those two nodes.

When a new node joins the CSN, it should calculate the propagation delay with each of the other nodes of the network.

The computation of the path delay between two nodes of the CSN network can be performed with two different schemes, depending on the hardware characteristics of the CSN nodes and the network as described in clauses J.4.2.1 and J.4.2.2.

J.4.2.1 ***Path delay measurement without network clock reference***

In the first scheme, each CSN node has a free-running local clock. The path delay measurement uses the protocol, messages, and state machines described in Clause 11 for 802.3 full-duplex, point-to-point links, as illustrated by Figure J - 6 .

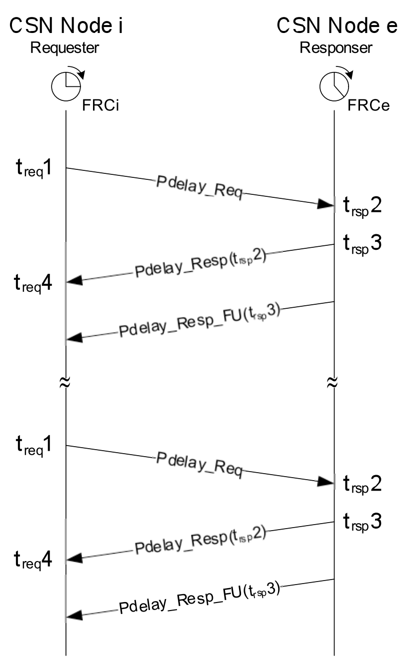

Figure J - 6 - CSN node to node path delay measurement

The computation of the neighborRateRatio and neighborPropDelay between two CSN nodes is done using the timestamps at the requestor and information conveyed in the successive Pdelay_Resp and Pdelay_Resp_Follow_Up messages. As one example, the neighborRateRatio is computed as the ratio between a time interval measured by the local clock of the responder and its associated time interval measured by the local clock of the requester, using a set of received Pdelay_Resp and Pdelay_Resp_Follow_Up messages and a second set of received Pdelay_Resp and Pdelay_Resp_Follow_Up messages some number of Pdelay_Req message transmission intervals later, i.e.,

$$\frac{(t_{rsp}3)_N - (t_{rsp}3)_0}{(t_{req}4)_N - (t_{req}4)_0} \qquad \text{(J-3)}$$

where $(t_{rsp}3)_k$ is the time relative to the local clock of the responder that the k^{th} Pdelay_Resp message is sent, $(t_{req}4)_k$ is the time relative to the local clock of the requestor that the kth Pdelay_Resp message is received, N is the number of Pdelay_Req message transmission intervals separating the first set of received Pdelay_Resp and Pdelay_Resp_Follow_Up messages and the second set, and the successive sets of received Pdelay_Resp and Pdelay_Resp_Follow_Up messages are indexed from 0 to *N* with the first set indexed 0. The neighborPropDelay between the time-aware system and the CSN node is computed as

$$\frac{(t_{req}4 - t_{req}1) * r - (t_{rsp}3 - t_{rsp}2)}{2} \qquad \text{(J-4)}$$

where *r* is equal to neighborRateRatio, $t_{req}1$ is the time relative to the local clock of the requestor that the Pdelay_Req message for this message exchange is sent, $t_{rsp}2$ is the time relative to the local clock of the responder that the Pdelay_Req message for this message exchange is received, $t_{rsp}3$ is the time relative to the local clock of the responder that the Pdelay_Resp message for this message exchange is sent, and $t_{req}4$ is the time relative to the local clock of the requestor that the Pdelay_Resp message for this message exchange is received.

Although the propagation delay between two CSN nodes is constant, a Pdelay_Req message should be periodically sent by each node to each other active node of the network to measure the neighborRateRatio between the node and each other node.

J.4.2.2 *Path delay measurement with network clock reference*

If the CSN Network Reference Clock (NRC) propagated to each node provides accuracy similar to the accuracy the pDelay protocol would provide, the CSN nodes do not need to send periodic PDelay messages:
- the CSN specific MD entity used its native path delay measured value for the computation of the correction field in the follow up message (cf equation J-7).
- since the clock is synchronized between the nodes, the rateRatio is equal to 1 and its calculation based on periodic pDelay messages (as described in section J.4.2.1) is not necessary.

J.5. *Synchronization messages*

To be part of the AVB cloud, the CSN network propagates 802.1AS time across the CSN network to CSN end stations and to downstream non-CSN links, as illustrated in Figure J - 7.

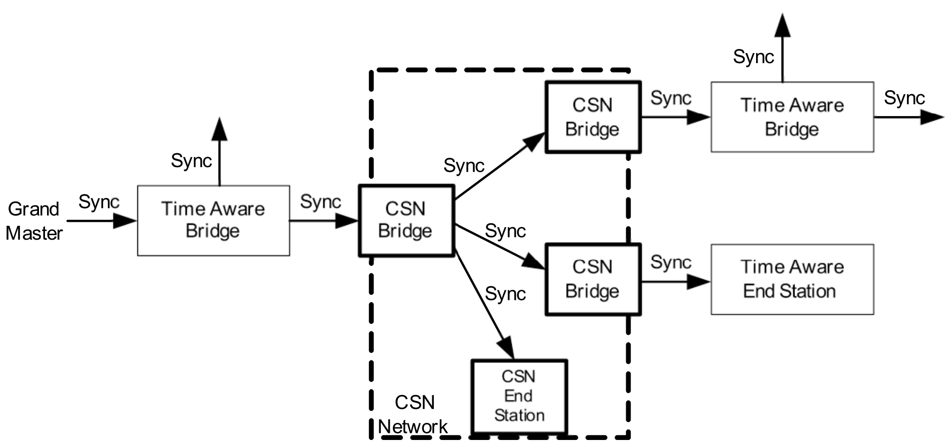

Figure J - 7 - 802.1AS Sync Message Propagation over the CSN backbone

Once the path delays have been measured (a) between the upstream 802.3 time-aware bridge and the ingress CSN node, (b) between the CSN nodes, and (c) between the egress CSN node and the downstream 802.3 time-aware bridge or end station, the CSN backbone can propagate the synchronization messages received at its boundary nodes.

The synchronization over the CSN backbone use the Sync and Follow_Up protocol, messages and state machines specified for 802.3 full duplex point to point links in Clauses 10.2 and 11.2.

Sync messages are propagated through the CSN network from a upstream node (aka ingress node) to all the downstream (aka egress nodes) of the network as illustrated in Figure J - 8

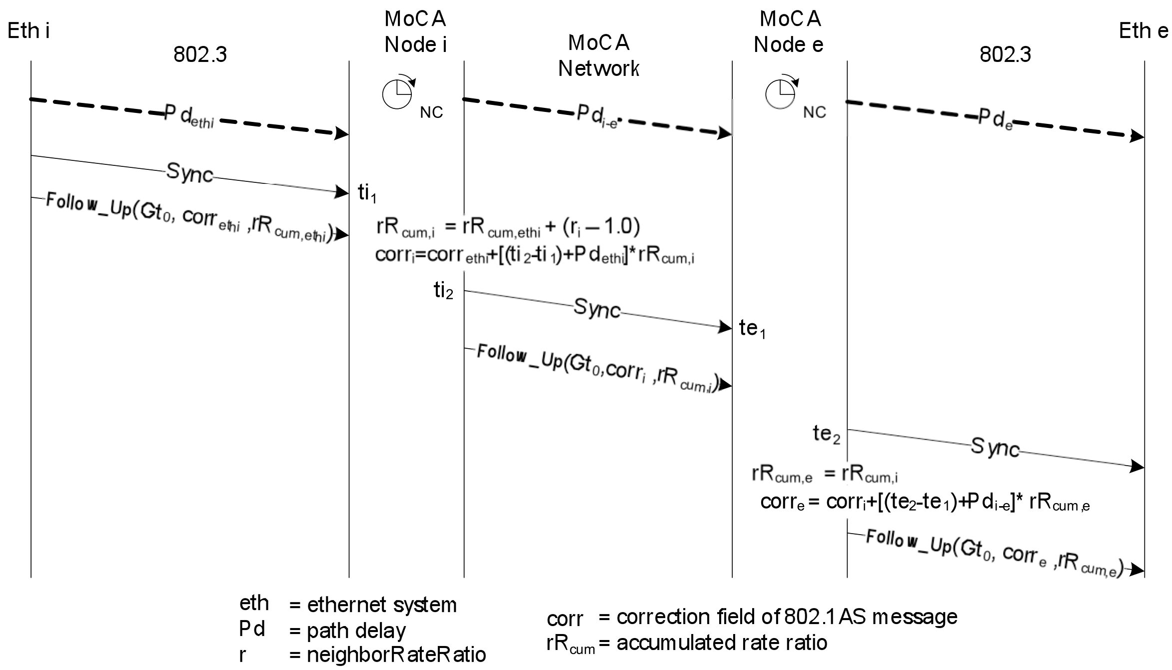

Figure J - 8 - Synchronization message propagation

The Sync message propagation is handled as follows:

1. The ingress CSN node ($Node_i$) receives a Sync message from the upstream TAS_i time stamped by its **own** network clock at time ti_1 relative to the local clock of the ingress CSN node.

2. The Follow_Up message indicates that the Sync message received at time ti_1 was sent by the grand master time gT_0 and that the sum of the residence times and link delays is equal to $corr_i$ and it also provides the accumulated rate ratio relative to the grand master time.

3. The Ingress $Node_i$ must schedule a Sync message for transmission onto the CSN link and, once the transmit timestamp ti_2 is available, must compute a new correction field using the residence time and upstream link delay, both corrected by the rateRatio.:

$$\mathrm{corr}_i = \mathrm{corr}_{ethi} + (\mathrm{Pd}_{ethi} + (\mathrm{ti}_2 - \mathrm{ti}_1)) * \mathrm{rR}_{cum,i} \qquad \text{(J-5)}$$

NOTE: 802.1AS requires one PortSync and one Media Dependent (MD) entity to be instantiated per logical port (i.e. per CSN link). A CSN node must behave equivalently.
Sync and Follow-Up messages could either be sent independently on each link or broadcasted. However if Sync and Follow-Up messages are broadcasted:

- *all PortSync/MD entity pairs except one must set the timeSyncInterval variable of their state machine equal to 127, causing them to not generate any Sync message.*
- *a dynamic selection of the Sync broadcaster MD entity will be needed (a CSN node could dynamically quit the CSN network) . Its algorithm is implementation specific and out of the scope of these specifications.*

4. The Ingress $Node_i$ must compute the new accumulated rate ratio based on the Ethernet PDelay mechanism as defined in clause 11.2):

$$rR_{cum,i} = rR_{cum,ethi} + (neighborRateRatio - 1.0) \quad (J\text{-}6)$$

5. The Ingress $Node_i$ must send Follow_Up messages to the other nodes of the CSN network with the updated $corrT_i$ timing information and the new accumulated rate ratio.

6. The Egress CSN Nodes ($Node_e$) receives the Sync message at time te_1 relative to the local network clock of the egress CSN node.

7. The Egress $Node_i$ MUST schedule a Sync message for transmission onto the Ethernet link (if any) and, once the transmit timestamp is available, MUST compute a new correction field using the residence time and CSN link delay, both corrected by the rateRatio:

$$corr_e = corr_i + (Pd_{i\text{-}e} + (te_2 - te_1) * rR_{cum,e}) \quad (J\text{-}7)$$

8. Each Egress $Node_e$ must send a Follow_Up message to their downstream TAS_e with the updated correction field $corr_e$ and the new accumulated rate ratio $rR_{cum,e}$.

J.6. Best Master Clock

J.6.1 Best Master Clock Selection

Each CSN Node should implement the Best Master Clock Selection algorithm as specified in 802.1AS/D5.0 Clause 10.3,

J.6.2 Best Master Clock Capable

Each CSN Node be Clock Master capable allowing a CSN node to act as the Grand Master clock either for a homogeneous CSN network, or for a heterogeneous network.

NOTE: 802.1AS requires one PortSync and one Media Dependent (MD) entity to be instantiated per logical port (i.e. per CSN link). A CSN node must behave equivalently.
Announce messages could either be sent independently on each link or broadcasted. However if Announce messages are broadcasted:

- *all PortSync/MD entity pairs except one must set the timeAnnounceInterval variable of their state machine equal to 127, causing them to not generate any Announce message.*
- *a dynamic selection of the Announce broadcaster MD entity will be needed (a CSN node could dynamically quit the CSN network) . Its algorithm is implementation specific and out of the scope of these specifications.*

J.7. CSN Clock Requirements

The CSN clock performances should comply with the requirements specified in Annex B.1