



802.1 TIME-SENSITIVE NETWORKING (TSN) ON 802.3CG MULTIDROP

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WHAT THIS PRESENTATION IS AND IS NOT

Two TSN standards will be presented:

- Time Synchronization (802.1AS a.k.a. AS); required for any TSN-based solution
- Scheduled Traffic (802.1Qbv a.k.a. Qbv); a possible solution for TDMA-like access on CSMA/CD multidrop. 802.1Qbv requires time synchronization to coordinate transmission schedules across devices and therefore relies on AS.

The intent of this presentation is to determine if a TSN-like environment can be built on a CSMA/CD multidrop medium. It does not attempt to address if it should be done. That is a decision for the 802.3cg Task Force.

Specific clause references in [IEEE Std 802.1AS-2011](#) and [IEEE Std 802.1Qbv-2015](#) are included to aid others in researching these topics further.

Caveat: This presentation represents the opinion of the author and is not an official presentation from the 802.1 TSN Task Group.

WHAT MULTIDROP SOLUTIONS HAVE BEEN PROPOSED TO DATE?

EPON over copper

- Node-to-node communication must go through the Master node, which means slave-to-slave communication uses twice the bandwidth
- Does this proposal include MPCP GATE & REGISTER_REQ messages used by AS (Clause 13, Annex F)?

PLCA (PHY-Level Collision Avoidance)

- Node-to-node communication is direct
- Efficient use of bandwidth with minimal COMMIT/YIELD signaling overhead per node
- Latency can have a lot of jitter, but does have a calculable min/max
- Need a new Study Group to standardize this solution

TDMA over CSMA/CD (802.1AS + 802.1Qbv)

- Node-to-node communication is direct
- Cannot mix TDMA nodes with non-TDMA nodes
- Unused time-slots are wasted
- Latency is consistent

Running 802.1AS (time synchronization) on multidrop

RUNNING 802.1AS ON MULTIDROP (SUMMARY)

While AS was originally targeted to run on point-to-point Ethernet links due to AVB's original goals, it grew to support shared media on IEEE 802.11, IEEE 802.3 EPON and other coordinated shared media links. Running AS on multidrop will need to consider these two 802.3cg multidrop characteristics:

Collisions

Based on David Brant's [Addendum to Discussion of Multidrop Access Methods](#) we can be sure that 802.3bf timestamps are valid on TX & RX packets. Any collisions can be detected and discarded outside of AS and AS will never see the collisions. Collisions on the TX side are handled since the 802.3bf TX timestamp delivered to AS will be for the successful TX packet. Likewise, RX timestamps will only be sent to AS when the associated RX packet is successfully received.

AS observed result would be that the RX packet may be delivered a little later than expected (because of collisions on earlier copies of the RX packet). This appears to AS as nothing more than a delayed AS packet, which can also happen when other frames are ahead of AS frames in the transmitter's egress queue.

Single Response

AS Messages use a multicast address 01-80-C2-00-00-0E (AS Tables 10-2 & 11-1), but only expect a single reply. If this multicast addressing is used on a multidrop network AS will be confused by multiple replies from all the other nodes on the shared media (AS 7.3.4, item b, 11.2.2). Therefore, a unicast addressing scheme (AS Annex E) must be implemented for some messaging.

802.1AS PROPAGATION DELAY COLLISIONS ON MULTIDROP

Diagram at right shows Pdelay exchange used to calculate propagation delay between nodes.

Propagation Delay formula (AS 11.1.2):

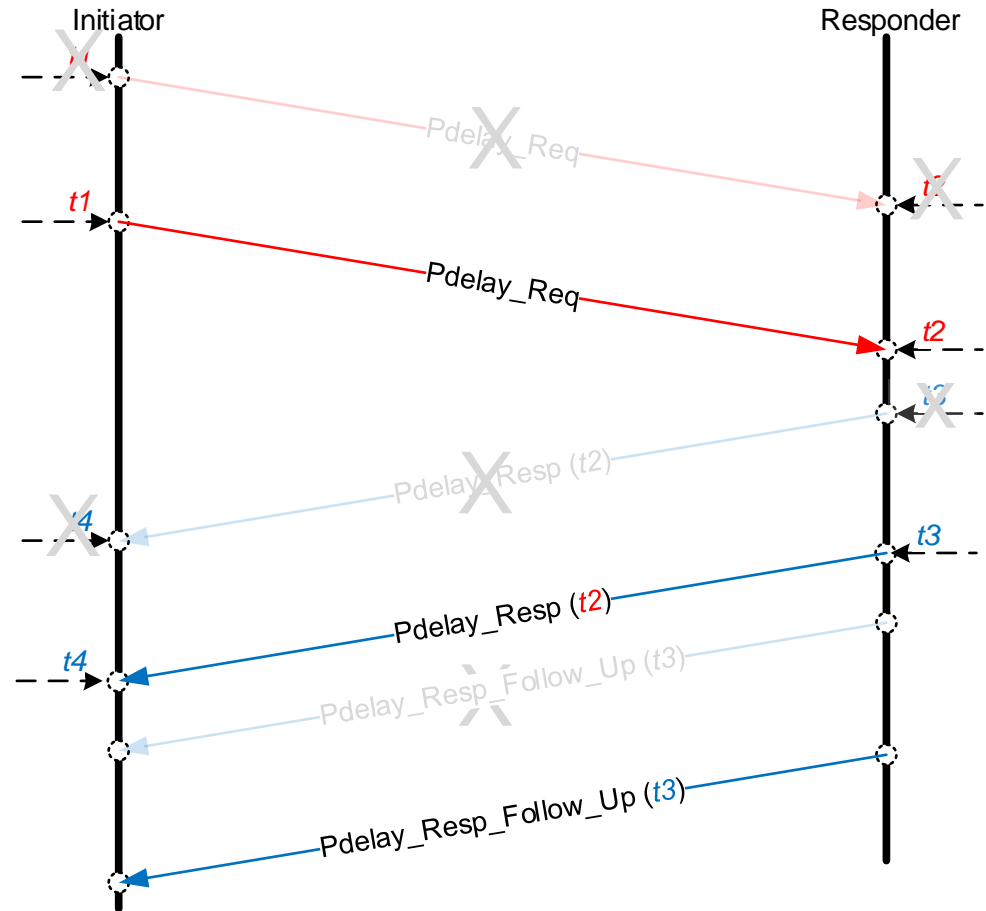
$$\frac{(t4 - t1) - (t3 - t2)}{2}$$

From the formula it is evident that the time between reception of the request ($t2$) and transmission of the response ($t3$) is irrelevant since that is subtracted from the time associated with the entire request/response transaction ($t4 - t1$). Therefore, retries caused by collisions will not impact the

Pdelay measurements as long as Response and Follow Up are received before the next Request is sent. Pdelay measurements occur once per second (AS 11.5.2.2).

Note 1: Cannot use layer 2 multicast addressing; that is discussed in a later slide.

Note 2: The Pdelay mechanism is also used to compute the ratio of the frequencies of the local clock to the peer's local clock to more accurately compute the propagation delay.



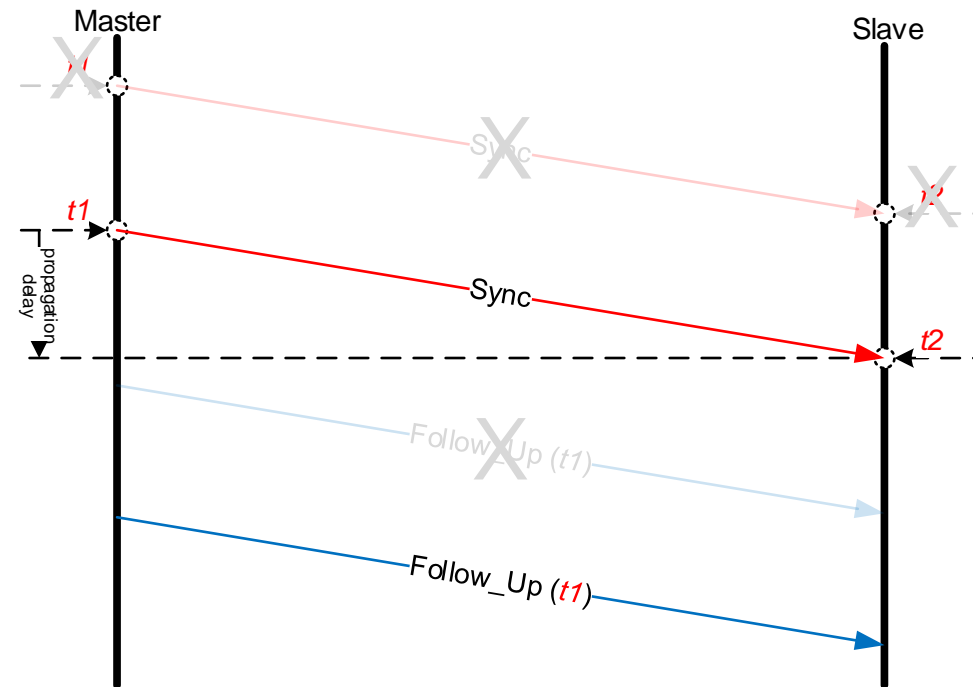
802.1AS TIME SYNCHRONIZATION COLLISIONS ON MULTIDROP

Diagram at right shows Sync messages used to synchronize time.

Sync and Follow_Up message pairs are sent from the Master to the Slave (or to multiple Slaves as is the case in this multidrop proposal). In this situation it is okay, and actually desirable, to use the AS multicast address so that all slaves learn the current time at once.

There is no particular requirement for how soon the Follow_Up must be transmitted after the Sync as long as it occurs before the next Sync is sent, which is 8 times per second (AS 10.6.2.3, 11.5.2.3). The longer it takes the more “stale” the time is.

Note: Follow_Up messages can also contain rate ratios and GM phase and frequency change information (AS 7.4).



802.1AS SINGLE RESPONSE ON MULTIDROP

Summarizing from the previous three slides:

1. Sync & Follow_up messages will use the layer 2 multicast address 01-80-C2-00-00-0E (AS Table 10-2 & 11-1). These messages are periodically sent from the Master to the Slave(s).
2. Announce messages should use the multicast address since there is no reply to these messages. Only the Master will periodically send this message.
3. Pdelay Request, Response, and Response Follow_up will use unicast addressing (AS Annex E). These messages are bidirectional between the Master and each Slave*.

The unicast addresses will be the MAC addresses of the devices in question.

ASSUMPTION: The Master will know the MAC addresses of all Slaves and all Slaves will know the MAC address of the Master.

* For shared media, we will need to run 802.1AS unicast, but there is plenty of precedent for that, so it is straightforward as an amendment.

How can unicast addresses be learned (not in AS - yet)?

IEEE 1588-Rev, Clauses 16.1, 16.9 and 17.4 discuss various options with regard to unicast addressing. One technique to accomplish unicast configuration is described in 16.9 where the Announce message can contain a PORT_COMMUNICATION_CAPABILITIES or a PROTOCOL_ADDRESS TLV that tells other stations to communicate with this station via unicast addressing.

802.IAS ON MULTIDROP? YES

Can 802.IAS (gPTP) run on a multidrop network? Yes.

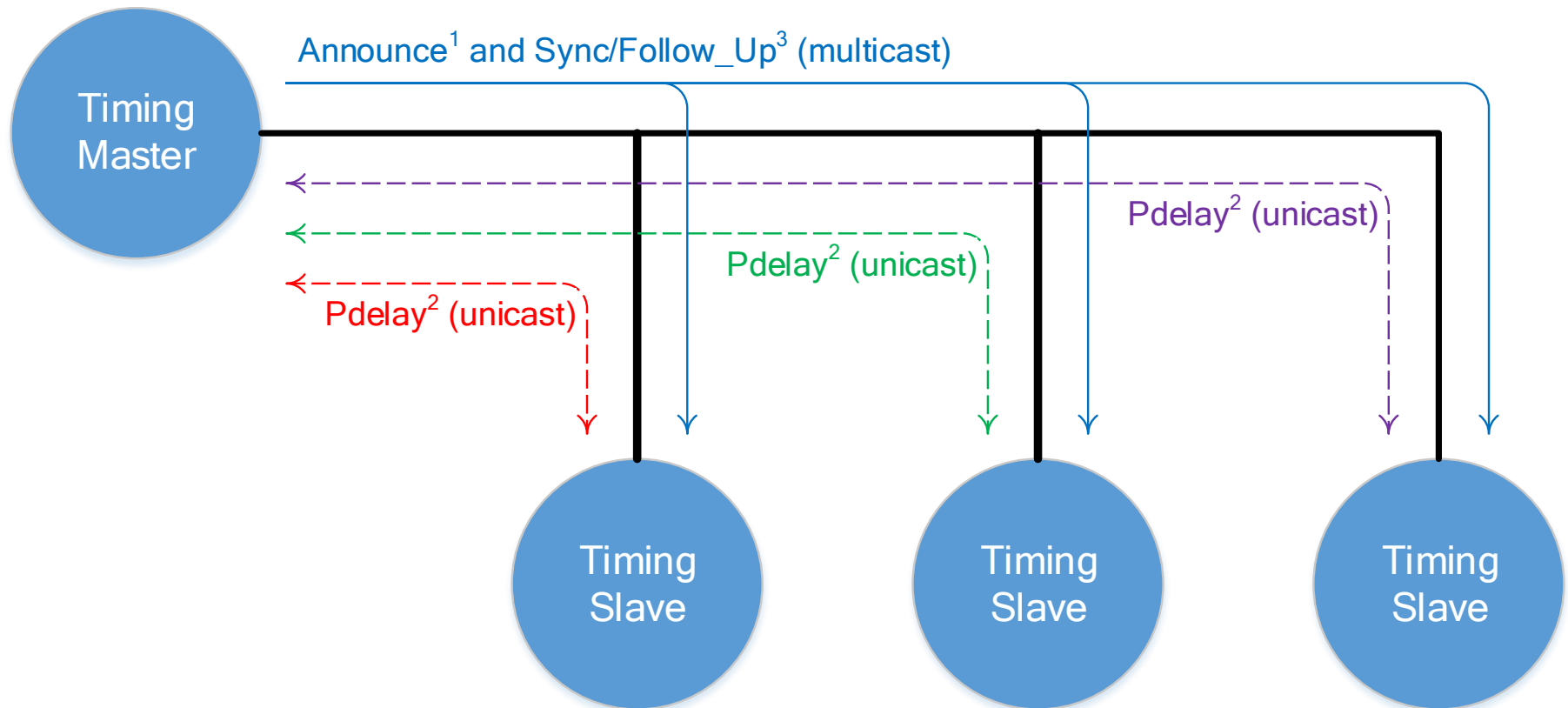
Here's the steps, assuming the timing Master for the multidrop segment will never change* (i.e. it is the port on the attached switch):

1. Master Announces itself to the network which allows Slave(s) to learn the Master's MAC address.
2. Slave(s) run Pdelay in unicast mode with the Master. Collisions will be handled appropriately. If the wire lengths are so short that the propagation delay is negligible it may be possible to skip Pdelay measurements in an engineered network. Slave(s) only need to track propagation delay to the single Master.
3. There is no need for the Master to run Pdelay propagation calculations against the Slave(s); therefore, Master does not need to track multiple delays.
4. Master transmits Sync & Follow_Up messages using the standard multicast address.
5. Slave(s) calculate current time by adding propagation delay (calculated by Pdelay) to the Master's gPTP time (*t_I* from the Sync's Follow_up packet).

* Note: I believe the assumption about a 'dedicated' Master is not actually required if all nodes transmit Announce packets and the BMC algorithm chooses the Master node the procedure described above will still work.

802.1AS ON MULTIDROP, PACKET EXCHANGES

The following diagram illustrates the packet exchanges detailed on the previous slide. In order to synchronize time, Slaves wait for (1) Announce which also contains the Timing Master MAC address, then run (2) Pdelay, then finally process (3) Sync/Follow_Up.



**Running 802.1Qbv (scheduled traffic)
on multidrop**

RUNNING 802.1Qbv ON MULTIDROP (SUMMARY)

An extract from the [Qbv PAR](#) states the scope of the amendment as:

enable bridges and end stations to schedule the transmission of frames based on timing derived from IEEE Std 802.1AS.

Assuming it is important on an 802.3cg multidrop network to get deterministic low latency behavior with reduced delivery variation from shared CSMA/CD media, this proposal will address the following multidrop characteristic:

Collisions

Collisions cause retransmissions which increase latency and add an unknown amount of delivery variation to packet data. In order to solve both problems (increased latency and delivery variation) a TDMA approach can be implemented based on Qbv.

Qbv is used to coordinate transmission of data from a group of devices egress queues. The transmission schedules created between various devices which are built on Qbv are synchronized by timing information provided by AS. Note that Qbv was carefully written so that any PTP timing protocol, such as 1588, can be used; however, TSN focuses on AS (gPTP).

Questions? Discussion?

Thanks!