Assumptions for Sources of Time Synchronization Error in IEEE 802.1AS
Rev 02

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Introduction

- This presentation provides a summary of assumptions pertaining to sources of error in 802.1AS time synchronization
  - A network that satisfies these assumptions will be capable of meeting the desired time synchronization accuracy of 1 μs over a maximum of 7 hops
  - It is intended that, after discussion and editing, these assumptions will be copied to the master list of AVB assumptions [1]
- This work was requested in the April 30, 2007 AVB timing call, after an initial discussion of sources of error based on [2]

Assumptions Relevant to AVB Time Synch

❑Network diameter

- Maximum diameter of any spanning tree of the network is 7 hops
  - This includes end stations
    - E.g., according to this definition, a direct connection between 2 end stations is 1 hop

❑Local oscillator quality

- ±100 ppm or better free-run accuracy
- Rate for 100 Mbit/s Ethernet is nominally 25 MHz
- Rate for GbE is nominally 25 MHz in some cases and nominally 125 MHz in some cases

❑PTP clock quality

- End-point time synchronization accuracy for steady-state operation is 1 μs or better over 7 hops
  - i.e., any 2 PTP clocks separated by at most 7 hops differ by no more than 1 μs
- End-point time synchronization accuracy during GM changes is TBD

Assumptions Relevant to AVB Time Synch

- Assumptions on error sources present in network, to meet the above time synchronization requirement for PTP clocks
  - Maximum frquency drift rate of local oscillator $\leq$ 1 ppm/s (this assumption, combined with maximum frequency offset of ±100 ppm, results in maximum time synchronization error due to this effect of $<$ 1 ns (see [2]))
  - Effect of frequency measurement granularity is negligible
    - e.g., if 32 bits is used to express the measured frequency offset, the maximum frequency error *due to this effect* is 2.3×10^{-10}

Assumptions Relevant to AVB Time Synch (Cont.)

- Assumptions on error sources present in network, to meet the above time synchronization requirement for PTP clocks (Cont.)
  - Effect of PHY latency asymmetry and phase measurement granularity for 100 Mbit/s Ethernet
    - Any PHY latency asymmetry can be known as part of the design and compensated for to within 18% of the maximum allowable PHY latency
    - This means that of the allowable PHY latency asymmetry of IEEE 802.3 for 100BASE-X (table 24-3, plus additional 16 ns; see [2]) of 476 ns per hop, the maximum remaining uncertainty after compensation is 86 ns/hop, or 602 ns for 7 hops
    - The cumulative time synchronization error due to phase measurement granularity over 7 hops is 280 ns (40 ns allowance per hop)
      - This assumes that the variation of this error is sufficiently fast that, with a Sync interval between 10 ms and 100 ms, the effect of this variation can be reduced by endpoint filtering
    - All the above error components, taken together, leave a margin relative to the total 1 μs of approximately 111 ns (11%)
      - i.e., (1000 ns) – (602 ns) – (280 ns) – (7 ns) = 111 ns

Assumptions Relevant to AVB Time Synch (Cont.)

- Assumptions on error sources present in network, to meet the above time synchronization requirement for PTP clocks (Cont.)
  - Effect of PHY latency asymmetry and phase measurement granularity for GbE, assuming a 25 MHz nominal frequency for the local oscillator
    - Any PHY latency asymmetry can be known as part of the design and compensated for to within 25% of the maximum allowable PHY latency
    - This means that of the allowable PHY latency asymmetry of IEEE 802.3 for 100BASE-X (table 40-14, plus additional 16 ns; see [2]) of 344 ns per hop, the maximum remaining uncertainty after compensation is 86 ns/hop, or 602 ns for 7 hops
    - The cumulative time synchronization error due to phase measurement granularity over 7 hops is 280 ns (40 ns allowance per hop)
      - This assumes that the variation of this error is sufficiently fast that, with a Sync interval between 10 ms and 100 ms, the effect of this variation can be reduced by endpoint filtering
    - All the above error components, taken together, leave a margin relative to the total 1 μs of approximately 111 ns (11%)
      - i.e., (1000 ns) – (602 ns) – (280 ns) – (7 ns) = 111 ns

Assumptions Relevant to AVB Time Synch (Cont.)

- Assumptions on error sources present in network, to meet the above time synchronization requirement for PTP clocks (Cont.)
  - Effect of PHY latency asymmetry and phase measurement granularity for GbE, assuming a 125 MHz nominal frequency for the local oscillator
    - Any PHY latency asymmetry can be known as part of the design and compensated for to within 35% of the maximum allowable PHY latency
    - This means that of the allowable PHY latency asymmetry of IEEE 802.3 for 100BASE-X (table 40-14, plus additional 16 ns; see [2]) of 344 ns per hop, the maximum remaining uncertainty after compensation is 120 ns/hop, or 840 ns for 7 hops
    - The cumulative time synchronization error due to phase measurement granularity over 7 hops is 56 ns (8 ns allowance per hop)
      - This assumes that the variation of this error is sufficiently fast that, with a Sync interval between 10 ms and 100 ms, the effect of this variation can be reduced by endpoint filtering
    - All the above error components, taken together, leave a margin relative to the total 1 μs of approximately 97 ns (10%)
      - i.e., (1000 ns) – (840 ns) – (56 ns) – (7 ns) = 97 ns

References

1. Don Pannell, *Audio/Video Bridging (AVB) Assumptions*, IEEE 802.1 AVB Conference Call, April 18, 2007 (available at http://www.ieee802.org/1/files/public/docs2007/avb-pannell-assumptions-0407-v4.pdf).
2. Geoffrey M. Garner, *Sources of Time Synchronization Error in IEEE 802.1AS*, April 29, 2007 (available at http://www.ieee802.org/1/files/public/docs2007/as-garner-error-sources-time-synch-0407.pdf).