60802 Time Sync – Error Generation Simulations Time Series Assumptions

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Version 1

References

[1] Geoff Garner, "Initial 60802 Error Generation Time Series Simulation Results, Version 1", IEC/IEEE 60802 Contribution, January 2024

Background

- Simulations carried out by Geoff Garner and presented in [1] indicated that most normative requirements were reasonable.
- Some simulations raised questions about the behaviour of Mean Link Delay.
- Other simulations seemed to indicate that normative requirements around Error Generation at and End Station may be too tight.
- Further simulations, including multiple replications are planned to continue investigating the validity of the normative requirements and provide additional data on the above two points.
- This document details the planned simulations and data analysis.

Summary

- One working theory regarding the behaviour of the Mean Link Delay is that it's due to unrealistically stable and precise simulation of Clock Source and Local Clock. This will be investigated via implementing small offsets or small amounts of clock drift.
  - This investigation will be carried out first. Results may affect subsequent simulations.
- The initial simulations did not include the recommended Rate Ratio Drift compensation algorithm for End Stations. The next round of simulations will include this.
- Multiple replications of various cases will be executed to investigate potential variation of the normative requirements.

Assumptions – 1

- Time Stamp Errors, Pdelay Intervals, Sync Intervals
  - Reference [1], Slides 9 & 10
- Residence Time
  - Node 1: N/A (No Residence Time at GM)
  - Node 2: 0 ns
  - Node 3: Reference [1], Slide 10
- Pdelay Turnaround Time
  - Node 1: 0 ns
  - Node 2: Reference [1], Slide 11
  - Node 3: N/A (Not relevant to outputs of interest)
- Path Delays
  - Node 1 → Node 2: 0 ns
  - Node 2 → Node 3: 454.21 ns (same as [1])
  - Node 3 → Node 4: N/A (not relevant to outputs of interest)

Assumptions – 2

- End Point Filter Bandwidth: 1 Hz
  - Possibility to run 0.7 Hz later if needed
- Drift Tracking Algorithms as described in Annex D.5.6 (IEC/IEEE 60802 d2.1)
  - Including algorithm for RR drift error correction at End Station
- Mean Link Delay Algorithm
  - Reference [1], slide 13, but…
  - Algorithm initialised with random value, probability...
    - Normal Distribution
    - Mean: 454.21 ns
    - Standard Deviation: 0.1 ns
  - …and the “startup” behaviour of the algorithm can be skipped; use the steady state behaviour from the start of the simulation.

Cases to Run

- 1 – **“No” Clock Drift**
  - 1 – Node 1 & Node 2: 0 ppm offset; No Clock Drift.
  - 1b – Node 1: 0 ppm offset; No Clock Drift
    – Node 2: +1 ppm offset; No Clock Drift
  - 1c – Node 1: 0 ppm offset; No Clock Drift
    – Node 2: Offset varies ±1 ppm, sinusoidal with 10 second period
- 2 – **Node 1: Clock Drift** per [1], slide 14, 3rd bullet point
  – Node 2: 0 ppm offset; No Clock Drift
- 3 – **Node 1 & Node 2: Clock Drift** per [1], slide 14, 3rd bullet point
- In all cases, Node 3: 0 ppm offset; No Clock Drift
- May adjust “stable” sections of cases 2 and 3 (outside of main frequency offset ramp) based on results of 1 vs 1b vs 1c

Outputs of Interest

- As [1]…
  - **Mean Link Delay** (Node 3 measurement of delay from Node 2 to Node 3; after averaging filter / algorithm)
  - **Path Delay Measurement** (Node 3 measurement of delay from Node 2 to Node 3; before averaing filter / algorithm)
  - **Unfiltered dTE** (at Node 3; not used in the planned analysis)
  - **M** - PreciseOriginTimeStamp+CorrectionField-(Working Clock at GM), when Sync is sent (by Node 3)
  - **N** – rateRatio field of Sync minus actual rate ratio, when Sync is sent (by Node 3)
  - **P** – rateRatioDrift field of Sync minus actual rate ratio drift, when Sync is sent
  - **Filtered dTE** (at Node 3)

Experiment 1 – Data Generation

- 100,000 s per Replication (27.8 hours)
- 300 Replications each of…
  - Case 1
  - Case 1b
  - Case 1c

Experiment 1 – Data Analysis – 1

1. For each case (1, 1b, 1c)…

- Generate Mean_Link_Delay over time for each Replication
  - By feeding Link Delay measurements into the Mean_Link_Delay algorithm

2. For 1 Replication (of 300) of 1, 1b and 1c (i.e. 3 different Replications)…
   - Plot Mean_Link_Delay over time

3. Generate Mean and Standard Deviation (σ) for Mean_Link_Delay across all 300 Replications over time
   - Interpolate as needed for each Replication then calculate mean and standard deviation for each second across all 300 Replications

- Plot Mean, Mean + 6σ, Mean -6σ over time (on a single chart)

Experiment 1 – Data Analysis – 2

1. For 1 Replication (of 300) of 1, 1b and 1c (i.e. 3 different Replications)…

- Analyse Link Delay Measurement distribution over time
  - Use raw Path Delay measurements, prior to processing by Mean Link Delay Averaging
  - Plot individual data points over time?
  - Plot short-term mean (1s? 5s?), percentiles (5^{th}, 25^{th}, 75^{th}, 95^{th}?), or 6σ range?
- Goal is to visualise the distribution of datapoints within the range
  - Geoff Garner to send raw data to David McCall for post processing

Experiment 1 – Data Analysis – 3

1. For one of 1, 1b or 1c (selection made based on results of prior Data Analysis 1 and 2)…for data between 500 s and 10,000 s…

- For each of the 300 Replications, calculate 14 values…
  - **Mean_Link_Delay**: Mean, Minimum, Maximum
  - **M**: Mean, Minimum, 5th Percentile, 95th Percentile, Maximum
  - **N**: Mean, Standard Deviation
  - **P**: Mean, Standard Deviation
  - **Filtered dTE**: Mean, Standard Deviation
- For each value, calculate the minimum and maximum across the 300 Replications

Experiment 2 – Data Generation

- 2,000 s per Replication (33.3 minutes)
- 1000 Replications of Case 2
  - Clock Drift at Node 1, per [1], slide 14, 3rd bullet point

Experiment 2 – Data Analysis

1. For one Replication, plot over time…
   - Mean_Link_Delay, Unfiltered dTE, M, N, P, Filtered dTE
2. For data between 1,005 s and 1,200 s (while Node 1 offset is ramping)…

- For each of the 1,000 Replications, calculate 14 values…
  - **Mean Link Delay**: Mean, Minimum, Maximum
  - **M**: Mean, Minimum, 5th Percentile, 95th Percentile, Maximum
  - **N**: Mean, Standard Deviation
  - **P**: Mean, Standard Deviation
  - **Filtered dTE**: Mean, Standard Deviation
- For each value, calculate the minimum and maximum across the 1,000 Replications

Experiment 3 – Data Generation

- 2,000 s per Replication
- 1000 Replications of Case 3
  - Clock Drift at Nodes 1 & 2, per [1], slide 14, 3rd bullet point

Experiment 3 – Data Analysis

1. For one Replication, plot over time…
    - Unfiltered dTE, M, N, P, Filtered dTE
2. For data between 1,005 s and 1,200 s (while Nodes 1 & 2 offsets are ramping)…

- For each of the 1,000 Replications, calculate 14 values…
    - **Mean Link Delay**: Mean, Minimum, Maximum
    - **M**: Mean, Minimum, 5th Percentile, 95th Percentile, Maximum
    - **N**: Mean, Standard Deviation
    - **P**: Mean, Standard Deviation
    - **Filtered dTE**: Mean, Standard Deviation
- For each value, calculate the minimum and maximum across the 1,000 Replications

Thank you