TimeMachines Time Server Accuracy
TM1000A and TM2000A

1 Introduction

The purpose of this paper is to discuss and demonstrate the accuracy of the TimeMachines GPS time server products, specifically the TM1000A and TM2000A. Using data collected by a hardware time-stamping Linux based system, the accuracy of the time servers can be graphically represented in both NTP and PTP modes. Also analyzed in this report are the effects of network jitter on timing accuracy of both models, and the holdover accuracy of the TM2000A.

2 Test Methodology

The method of evaluation is to use a “known accurate” timing source as a reference to the time provided by the TimeMachines TM1000A and TM2000A. In this case, a Microsemi TimeProvider 2700 with GPS input, a NIST certified time source, was used as the reference for all measurements.

In all graphs, the TimeProvider 2700 will be shown as Source 0 using PTP protocol as the point of comparison. The clock of the computer is compared to Source 0 and all incoming time packets, both PTP and NTP, are hardware time-stamped and compared against the computer clock to determine their offset from the reference time provided by Source 0. Sample rates of the NTP points are greater than 1 sample per second. Long data sets have been recorded to confirm that the plots used in this analysis are representative of the product's accuracy, but the reduced time sets will be used here to make the details of the graphs clear.

3 Basic Accuracy

3.1 Figures 1 & 2 – Raw Accuracy

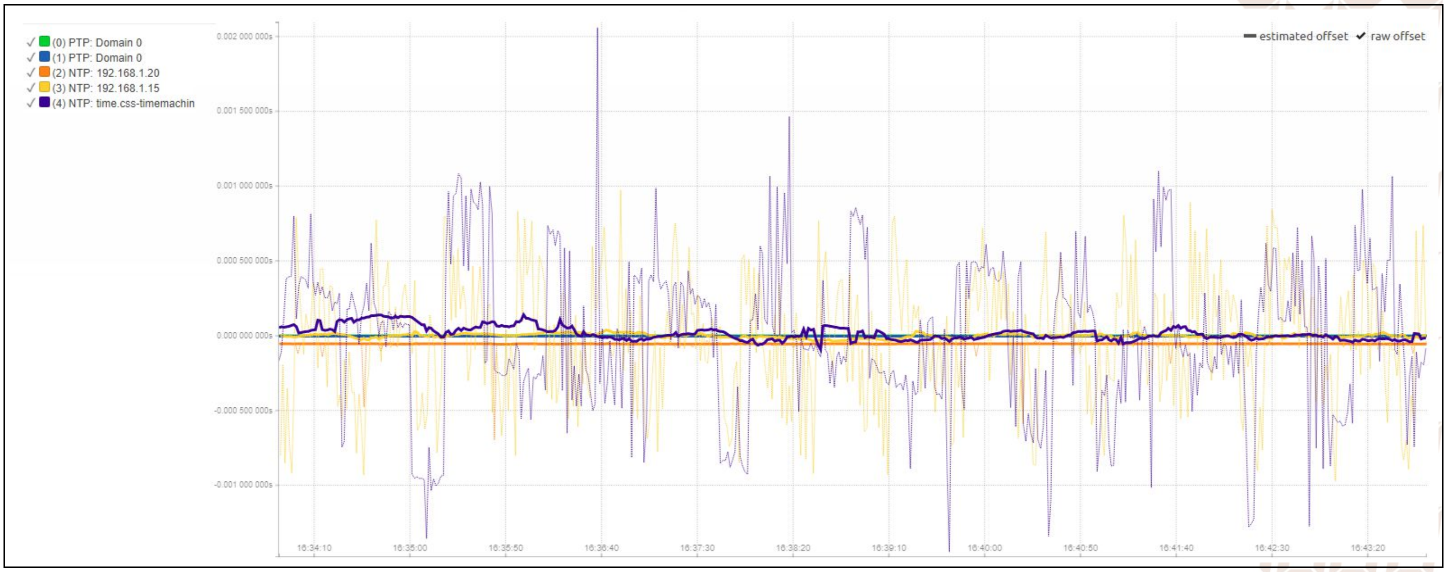

Figure 1: All Sources - 10 Minute Span - Raw Data Points

Figure 1 shows all of the input sources in use. Those sources are:

- Source 0: Microsemi TimeProvider 2700, PTP mode, Reference Source
- Source 1: TimeMachines TM2000A, PTP mode
- Source 2: TimeMachines TM2000A, NTP mode
- Source 3: TimeMachines TM1000A, NTP mode, local network connected
- Source 4: TimeMachines TM1000A, NTP mode, connected offsite via Internet through port forward. Round trip delay is approximately 4ms between the test location and the remote TM1000A.

The dark lines show the smoothed (averaged) version of each source. It should be noted that the averaged data of all sources exist well within 0.0005 second accuracy. The data displayed by the fine lines is raw data, which, in this view, are the actual samples from Sources 3 and 4. The TM1000A on the local network, Source 3, has all of its data within +/- 0.001 seconds of the reference, which is consistent with the internal timekeeping parameters of the TM1000A. The TM1000A that is being monitored through the Internet connection, Source 4, shows a wider variation of accuracy with most points falling within the +/- 0.0015 range, but at least 1 point greater than 0.002 seconds offset from the reference. This is simply due to the additional network jitter introduced by the Internet connection.

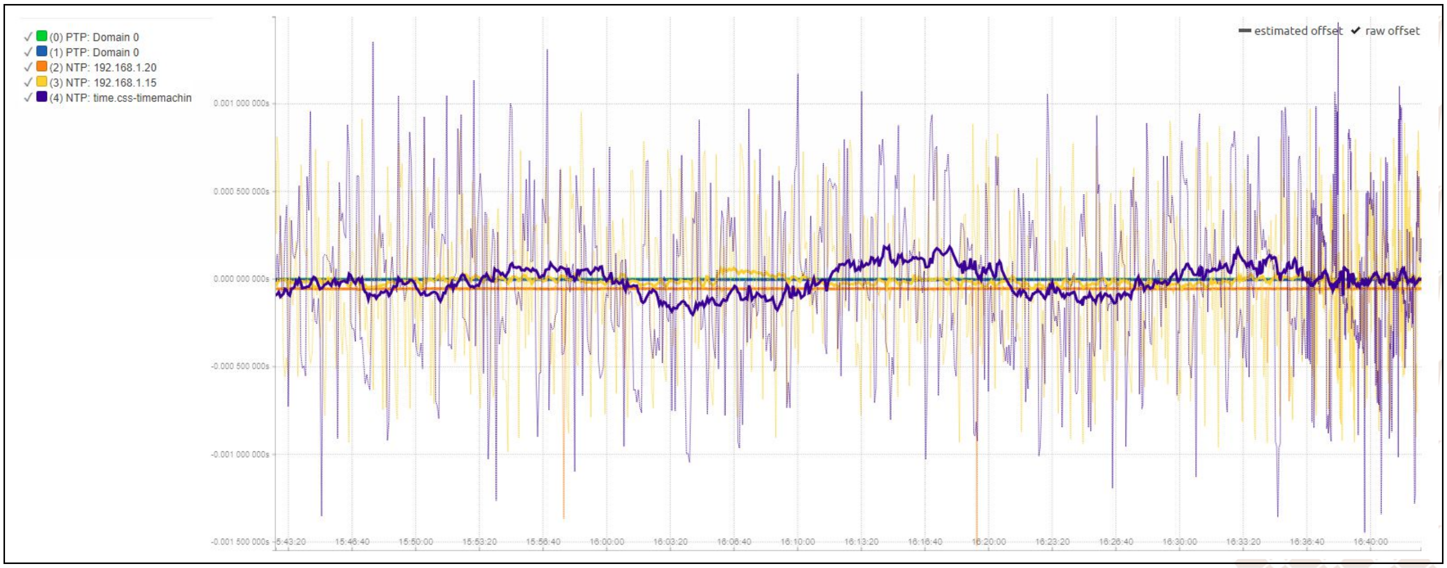

Figure 2: All Sources - 1 HR Span - Raw Data Points

Figure 2 shows essentially the same data as Figure 1, except that the span of time is 1 hour rather than 10 minutes. It shows the same accuracy and increased jitter introduced by the Internet connected TM1000A.

3.2 Figure 3 - Averaged Time Data

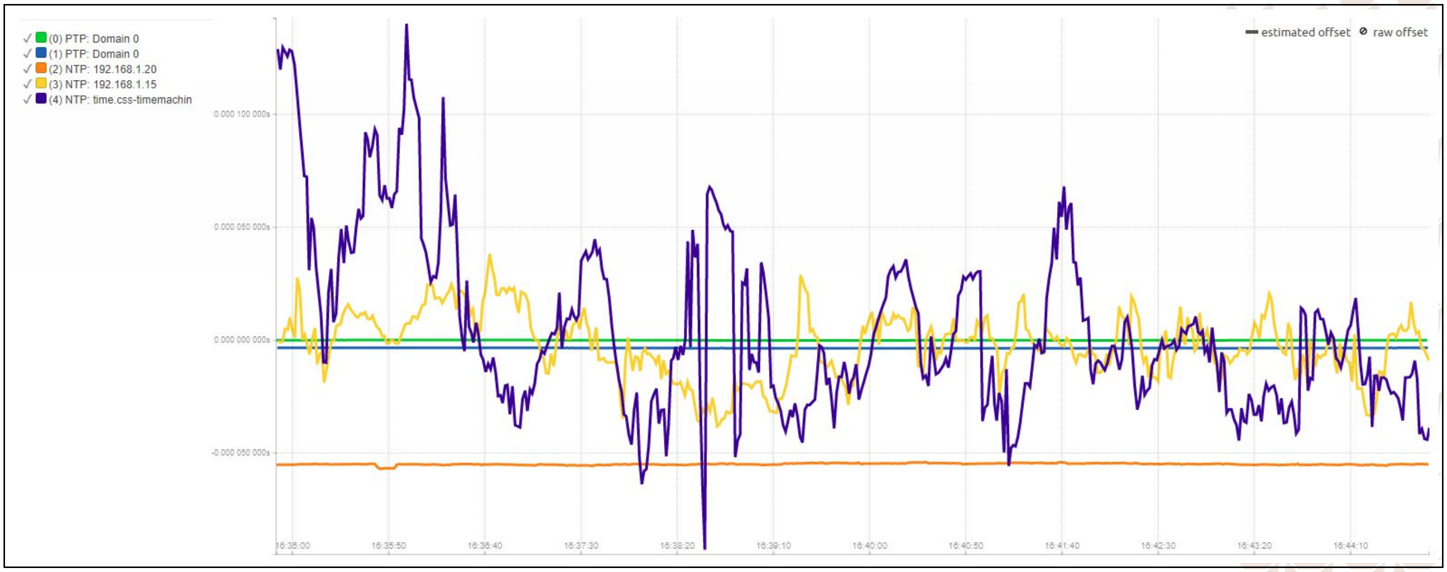

Figure 3: All Sources - 10 Minute Span - Averaged Data

Figure 3 shows all sources plotted over a 10 minute span, however the raw data points are removed and only the smoothed/averaged times are displayed. From this plot, a more refined accuracy can be seen for each device. Source 0 is the reference source and its plot is show as the zero line of the chart. Source 1, TM2000A PTP mode, is tracking Source 0 very closely within about -3.5uS. Source 2, TM2000A NTP mode, tracks the reference at a little greater than -0.00005 seconds, 50uS, of accuracy. The TM2000A has to maintain a very accurate internal time to maintain its PTP accuracy, and this shows up in significantly improved NTP performance compared to the TM1000A. With the raw data being averaged, as is common in many NTP devices, Source 3 maintains an averaged accuracy sub 50uS although with significantly more variability than Source 2. Source 4 accuracy, because of the internet induced jitter, is a bit worse at around 150uS.

3.3 Figure 4 – PTP Accuracy

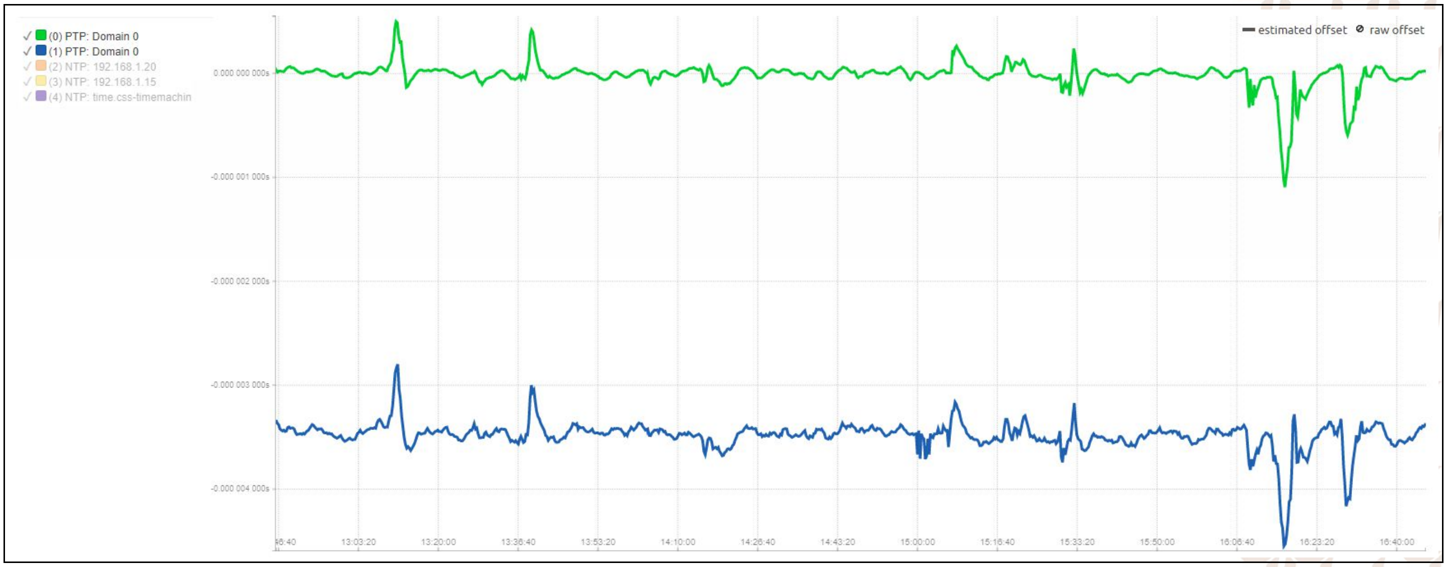

Figure 4: PTP Sources - 4 Hour Span - Smoothed Data

The TM2000A PTP accuracy can be viewed best in Figure 4. Its accuracy is maintained in the -3.5uS range through the displayed 4 hour plot. Notice that the irregularities in the plots are reflected in both the reference plot and the Source 1 plot. Because these irregularities are reflected in each plot, it is assumed this this is the base level jitter of the hardware clock in the test platform, and not a result of some inaccuracy of the time sources.

3.4 Figure 5 – TM2000A NTP Jitter

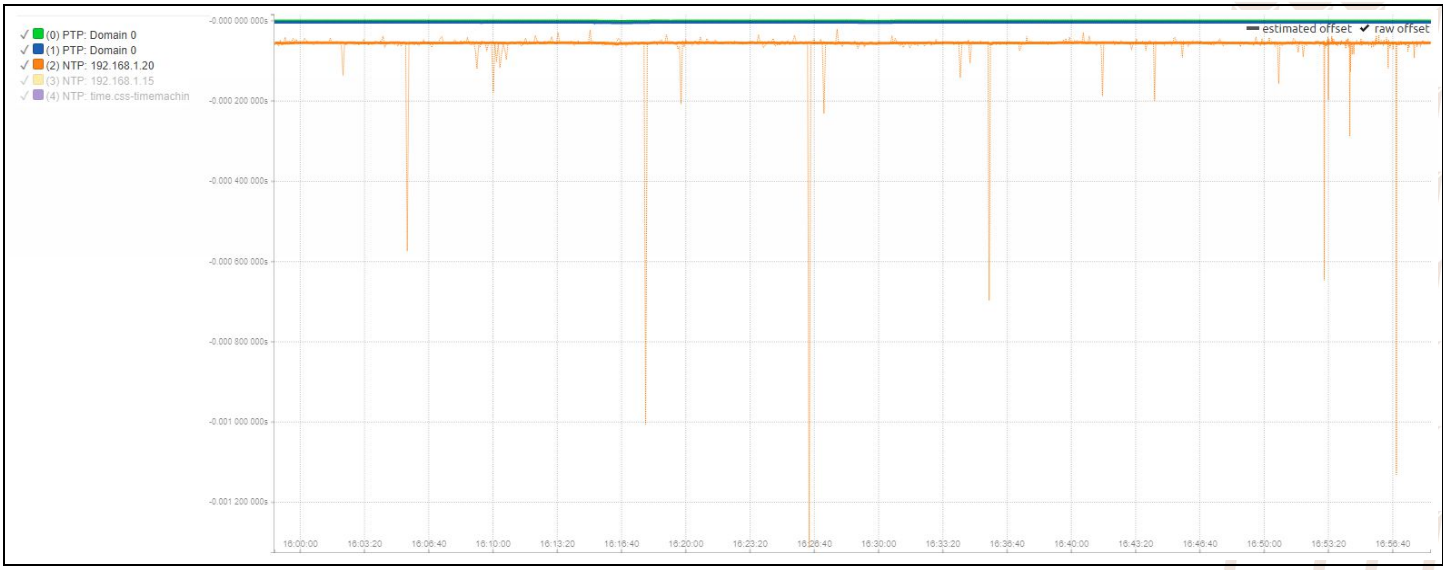

Figure 5: PTP and TM2000A NTP - 1 HR Span - Raw Data Points

Figure 5 is included to show the actual data of the TM2000A NTP data. It was previously noted that the average offset of the TM2000A in NTP mode, plotted in Figure 3, is consistent in the -50uS range. The TM2000A NTP accuracy and stability exceeds that of the TM1000A noticeably. NTP clients would generally average out those outlying points and, given the normal sample rate of NTP, would rarely be seen.

4 TM2000A Holdover Performance

The TM2000A contains a 20ppb Oven Controlled Oscillator (OCXO) that allows it to maintain its internal clock in the absence of a GPS signal for a period of time. This clock source is then used to serve time during GPS signal loss. The TM1000A does not have an OCXO internal clock and thus does not continue to serve time if its GPS lock is lost.

4.1 *Figure 6 – 4 HR PTP Holdover Performance*

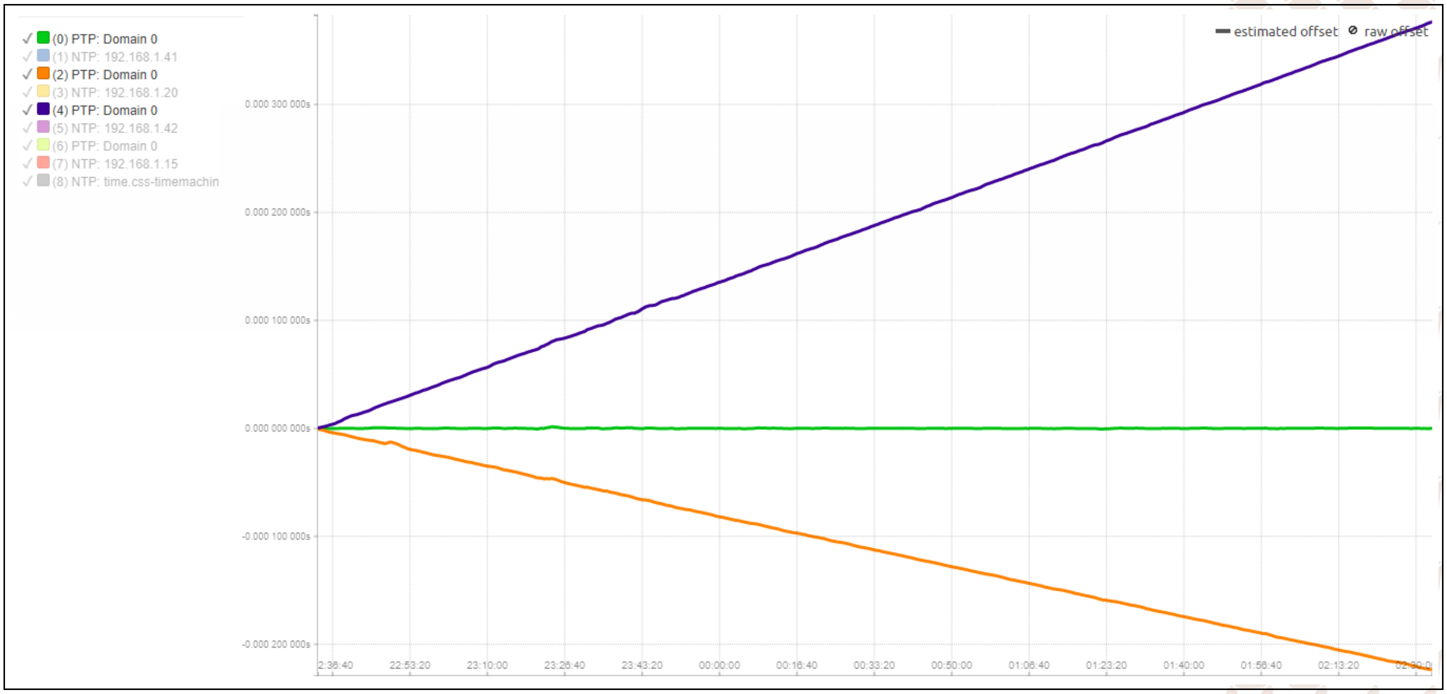

Figure 6: PTP Holdover Accuracy - 4 Hr Span – Smoothed Data

Figure 6 shows the holdover performance of the TM2000A for PTP timing with smoothed data, however the timing sources have been changed from the previous section of this document. Timing Source 0 in this figure is a TM2000A whose GPS antenna is not disconnected during the test. Source 2 and Source 4 are are the PTP timing of two other TM2000As that have effectively lost the GPS signal input.

The internal frequency accuracy of the OCXO of each of the TM2000As under test are slightly different. This can be seen in that Source 2 is actually running slightly slower than nominal and over 4 hours it ends up approximately 225uS *behind* the reference source. Source 4 on the other hand is running a little bit faster than nominal and after 4 hours is almost 400uS *ahead* of the reference source.

This plot shows the relative variability of the TM2000A based on the accuracy of the OCXO. When tested prior to this plot, the reference TM2000A was running slower than nominal, but was much closer to the published frequency of the OCXO and as such its holdover accuracy was about 100uS behind reference after 4 hours.

4.2 *Figure 7 – 12 Hour Holdover Performance for PTP and NTP*

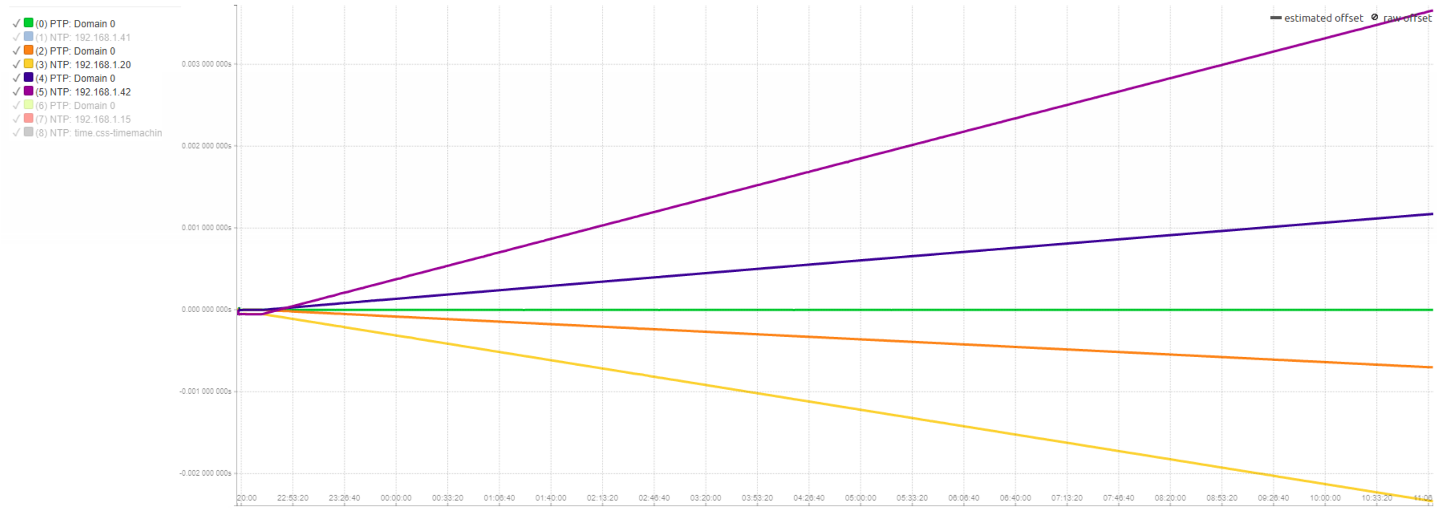

Figure 7: PTP and NTP - 12 Hour Span - Smoothed

Figure 7 is the same configuration of comparisons as in Figure 6 where Source 0 is a TM2000A with GPS signal intact, but it also includes the NTP performance of the other two TM2000A units. Thus, in this figure, Source 3 is the NTP performance of Source 2, and Source 5 is the NTP performance of Source 4. The plot shows the performance of the TM2000A after 12 hours with no GPS signal for both PTP and NTP holdover. Accuracy of each source over time is displayed in the table below:

	0 Hr	1 hr	4 hrs	12 hrs	Offset / HR
Source 2 - PTP	0	-55uS	-220uS	-670uS	-55uS
Source 3 - NTP	-50uS	-225uS	-775uS	-2.2mS	-180uS
Source 4 - PTP	0	+90uS	+375uS	+1.1mS	92uS
Source 5 - NTP	-50uS	+240uS	+1.1mS	+3.5mS	+295uS

4.3 *Overall Holdover Performance*

Holdover performance is based almost entirely on the accuracy of the clock source in the TM2000A and its stability. Even with a highly stable and accurate time source, there is variability from one device to the next. Based on a sample set of TM2000A tested, NTP accuracy is expected to degrade approximately 200-300uS per hour and PTP accuracy approximately 50 to 100uS per hour. Based on needed accuracy for any application, GPS lock must be maintained to ensure timing accuracy is not lost over time.

5 Conclusions

The TimeMachines TM1000A and TM2000A represent breakthrough performance for their price points. Work will continue on these and other new products to improve their accuracy and to bring new features. As always, we appreciate our customers support and constructive feedback to continue and enhance this development!