Improving MetaWatch's timestamp accuracy with clock modules

MetaWatch is a powerful FPGA network application designed for Arista's 7130 platform which simplifies network data capture, monitoring and analytics. It combines several components of a traditional network monitoring solution into one device:

- Tapping
- Tap Aggregation
- Precise Time Synchronisation
- Deep Buffering
- Sub-nanosecond accurate time stamping

The Arista 7130 FPGA-enabled devices can be ordered or upgraded with clock module options designed to improve MetaWatch's accuracy. These clock module options come in two varieties: an oven-controlled crystal oscillator (OCXO) and a rubidium oscillator (Atomic Clock). The 7130K and L series devices have an OCXO by default and can be upgraded to an atomic clock.

Arista recently performed in-house tests to quantify the difference that oscillator stability has on short term timestamp deviations when disciplined from a stable reference. For this we compared a standard crystal oscillator, an oven-controlled oscillator and a rubidium oscillator.

Clock module comparison - Method & Results

a) Method

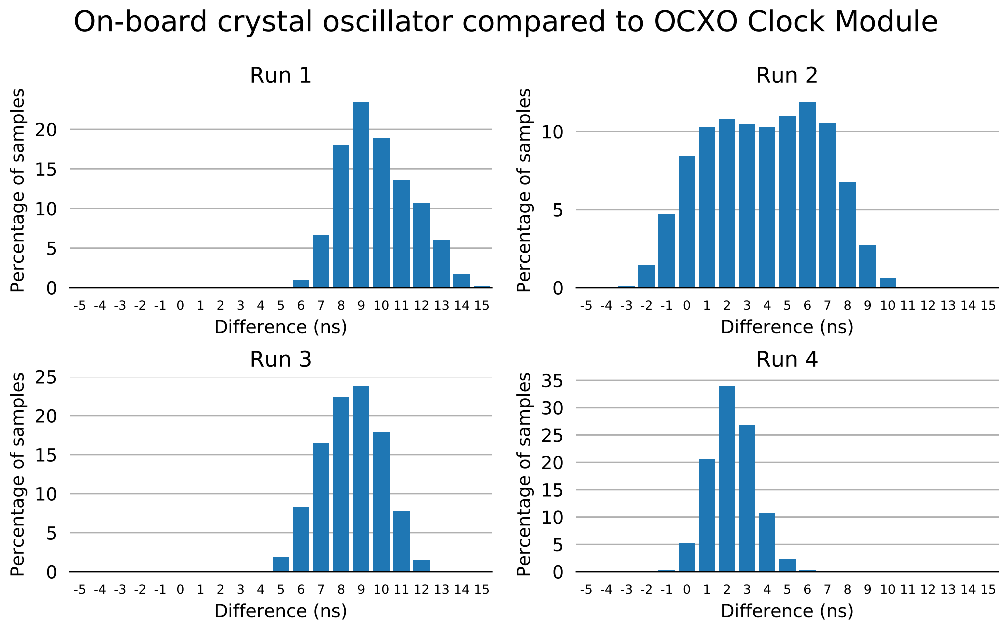
Three Arista 7130-32K devices running MetaWatch 0.6.1 were used to simultaneously timestamp the same stream of incoming Ethernet packets. Each device was fed PPS from a TimeTech 10535 pulse distribution unit, with output port-to-port jitter of <20 ps, connected to a SRS FS725 rubidium frequency standard with PPS output jitter of <10 ps. The Ethernet stream was fanned out via an Arista 7130 96-port Layer 1 switch. One of the Arista 7130-32K devices contained the Atomic Clock module while another contained the OCXO module. In each device MetaWatch was configured to use the Atomic clock module, the OCXO module and the crystal oscillator respectively.

The timestamped streams were then aggregated and captured to disk for analysis. This analysis involved comparing the timestamps applied by each device and measuring any differences between the timestamps applied by MetaWatch using the different oscillators. To capture as much timestamp granularity as possible a ~5 second 10GbE line-rate stream of 64-byte frames comprising over 70 million packets was used. The test was repeated for a total of four times.

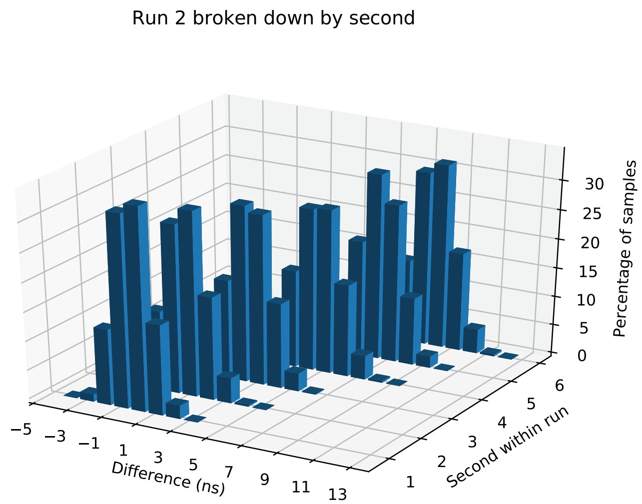
b) Results

1. Crystal Oscillator compared to the OCXO Clock Module

The following histograms show the distribution of the timestamp difference in nanoseconds between the same packets timestamped using the crystal oscillator and the OCXO Clock Module:



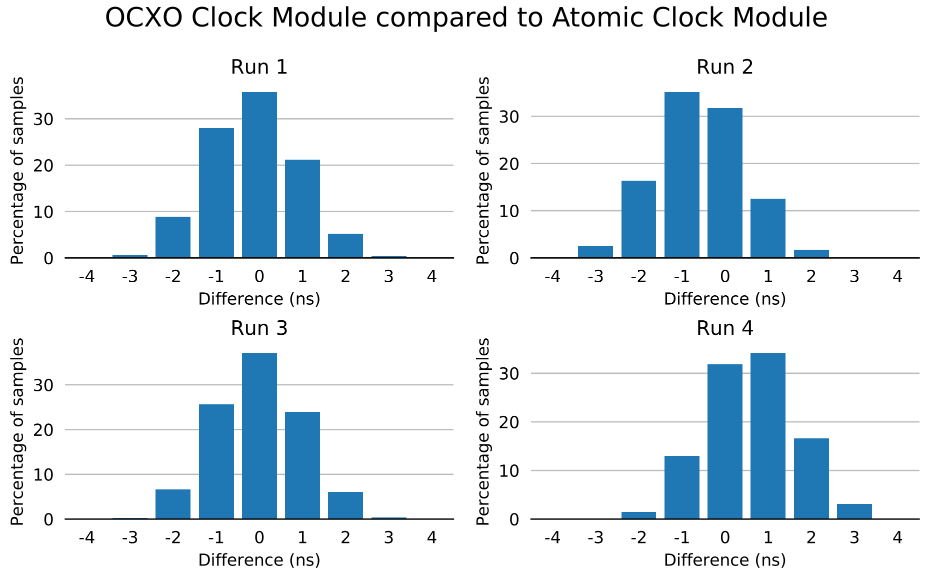
Across all four test runs, all timestamps derived from the crystal oscillator and the OCXO were within -4/+15 ns of each other. The histogram for Run 2 has a much wider distribution than the other three runs. When broken down by second, as shown below, the extended width of the histogram is due to the relative difference between the crystal and the OCXO changing over multiple seconds rather than excessive oscillator instability as the oscillator phase and frequency are adjusted by MetaWatch based upon the PPS pulse so corrections occur every second.



Though the crystal offers good stability over fractions of a second, over longer timeframes (seconds), it wanders relative to the PPS reference.

2. OCXO compared to the Atomic Clock

The following charts show the distribution of the timestamp difference in nanoseconds between the same packets timestamped using the OCXO Clock Module and the Atomic Clock Module:



Across all four test runs, all timestamps derived from the different clock modules were within ±4 ns of each other and 82.5% were within ±1 ns of each other.

It must be noted that this test is actually measuring not just the stability of of the clock modules but also the ability of two MetaWatch instances to synchronise to a PPS source; any synchronisation error from either device will be reflected in the delta between timestamps.

These results bear comparison to the NTE2 test in the STAC-TS benchmark report for MetaWatch that was run in 2017. This test specifically measured the accuracy of MetaWatch's timestamps to its PPS source.

The STAC-TS.NTE2 results tested on MetaWatch 0.5.2 were 100% of values within -3/+2 ns of the PPS reference. Substantial improvements have subsequently been made to MetaWatch's timestamp accuracy in the current version. The histogram distribution of these results being only marginally wider than the STAC-TS.NTE2 result demonstrates not only the short-term stability of the OCXO but the improved timestamp accuracy of MetaWatch.

Clock module comparison - which one is right for you?

As illustrated above the fundamental benefits of the OCXO and Atomic Clock Modules are improved short-term stability. Based upon the results of our testing individual timestamps relative to each other obtained from capturing market data for multiple hours could vary by ±15 ns on the same device with the potential for ±30 ns across multiple devices using the crystal oscillator.

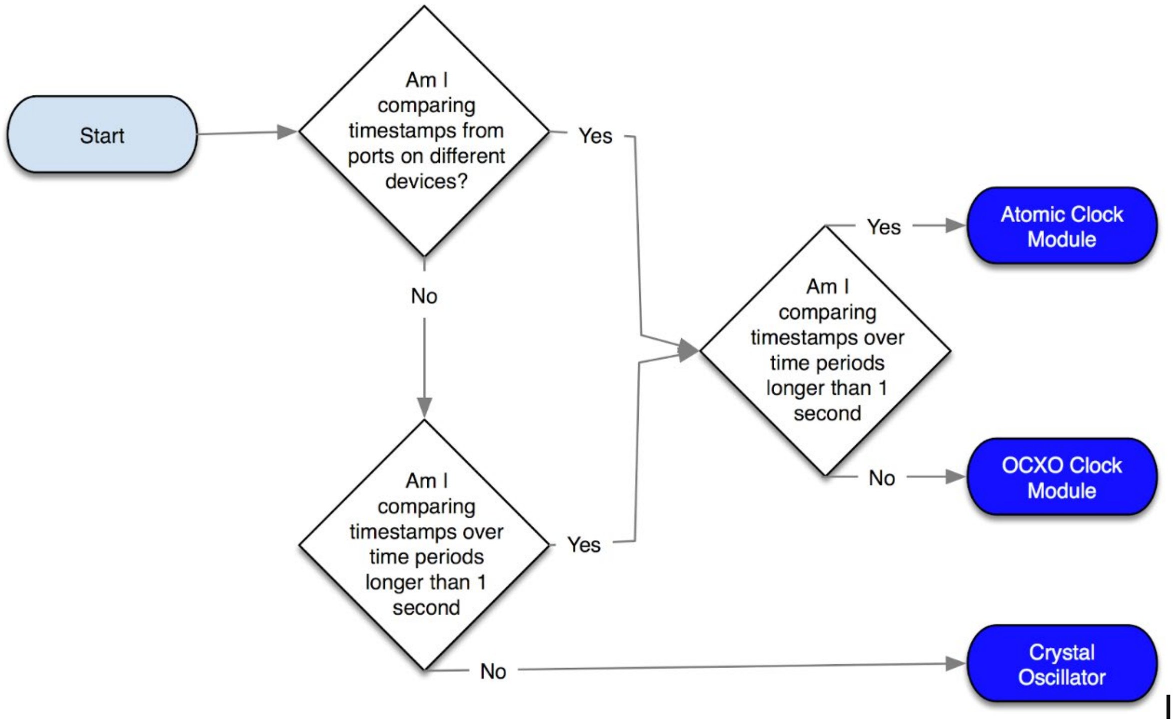
The same capture using the OCXO or Atomic Clock Modules would reduce that to just ±4 ns across multiple devices. Another point to keep in mind is that Arista continues to improve the accuracy of MetaWatch's timestamping as we release new versions so we expect the timestamp error to keep being reduced.

It will always be limited by the stability of the oscillator used as the frequency reference. With the OCXO and Atomic Clock Modules under PPS discipline Arista's goal is to achieve true sub-nanosecond accuracy across multiple devices.

Though both the OCXO and the Atomic Clock Modules exhibit the same short-term stability they exhibit rather different longer term stabilities. This is simply a function of the way that the different types of oscillators keep time. OCXO's will generally drift by no more that 100 us to 1 ms after running for 24 hours whereas rubidium atomic clocks are significantly more stable generally drifting single-digit microseconds in 24 hours.

Choosing the Atomic over the OCXO Clock Module therefore makes sense if there is a chance that MetaWatch will need to free-run for extended periods of time while remaining as accurate as possible.

We put together a flowchart, to help in potential clock module selection:



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