STAC Update:
Fast Data

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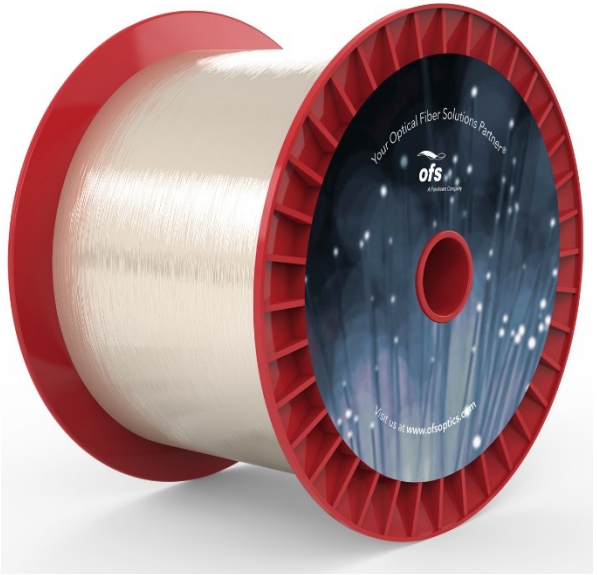
Two topics to discuss

- Latency study of OFS AccuCore HFC Hollow Core Fiber
- FPGA Special Interest Group update

Latency Study of OFS AccuCore HCF™ Hollow Core Fiber

- Is it possible to remove nanoseconds by simply replacing fiber optic cable?
  - OFS claims you can do just that with AccuCore HCF
- OFS asked STAC, as an independent 3rd party, to:
  - Compare latency difference of AllWave FLEX Max Optical Fiber (single mode fiber), AccuCore HCF Fiber Optic Cable (hollow-core fiber)
  - Basic measurements comparing different lengths of HCF and SMF



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Latency Study of OFS AccuCore HCF™ Hollow Core Fiber

- Compared 100m as the primary stack under test (SUT)
  - A proxy for long runs in data center (i.e., “meet me” room to cage, or cage to cage)
  - Easy to extrapolate to longer runs
  - Long enough where timestamp error becomes negligible when calculating implied per-meter latency improvement
  - Tested a single 100m cable containing 2 x HCF and 2 x SMF, using one fiber of each

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Latency Study of OFS AccuCore HCF™ Hollow Core Fiber

- Secondary SUT
  - Tested two shorter lengths to make sure there weren't major inconsistences in manufacturing
- 10m cables
  - Proxy for rack-to-rack networking in same cage
  - Tested 2 10m cables: one with 2 x HCF and & 2 x SMF, one with 4 x SMF
- 3m cables
  - Proxy for intra-rack cabling
  - Tested 2 3m cables: one with 2 x HCF and & 2 x SMF, one with 4 x SMF

Report coming soon

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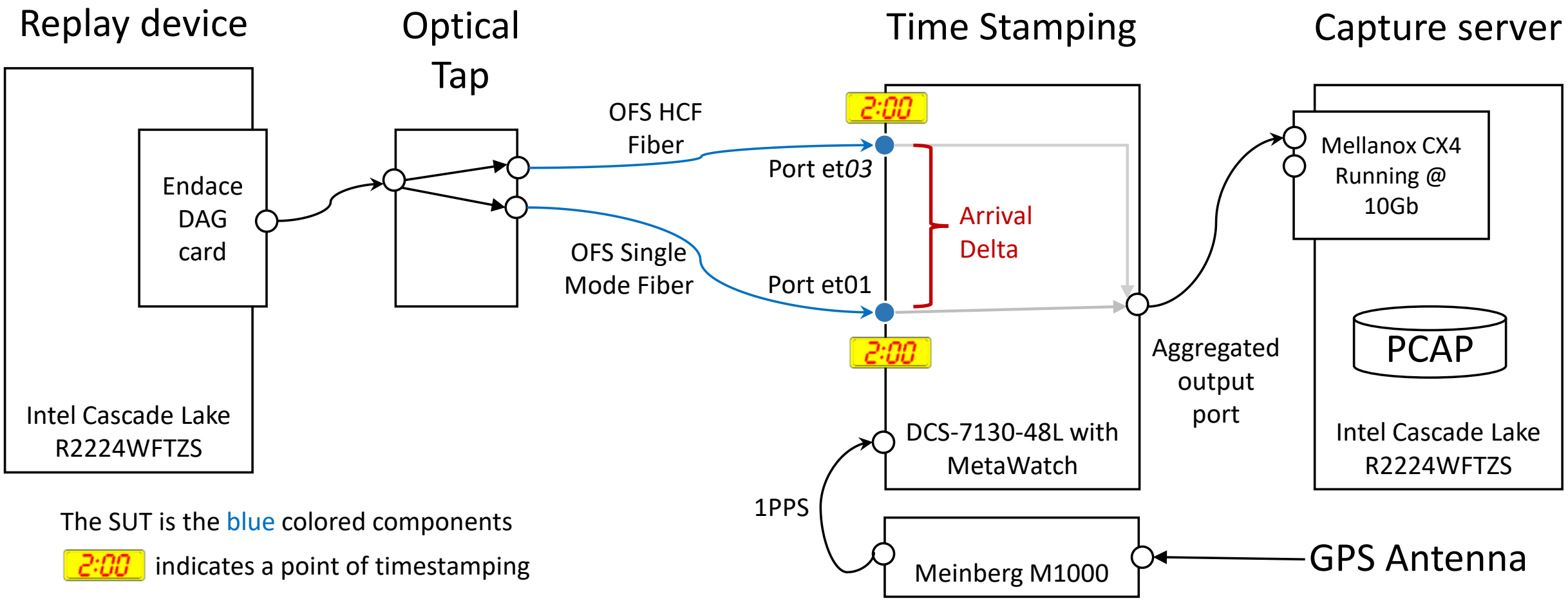
Test setup



The SUT is the blue colored components

2:00 indicates a point of timestamping

The management network is not shown

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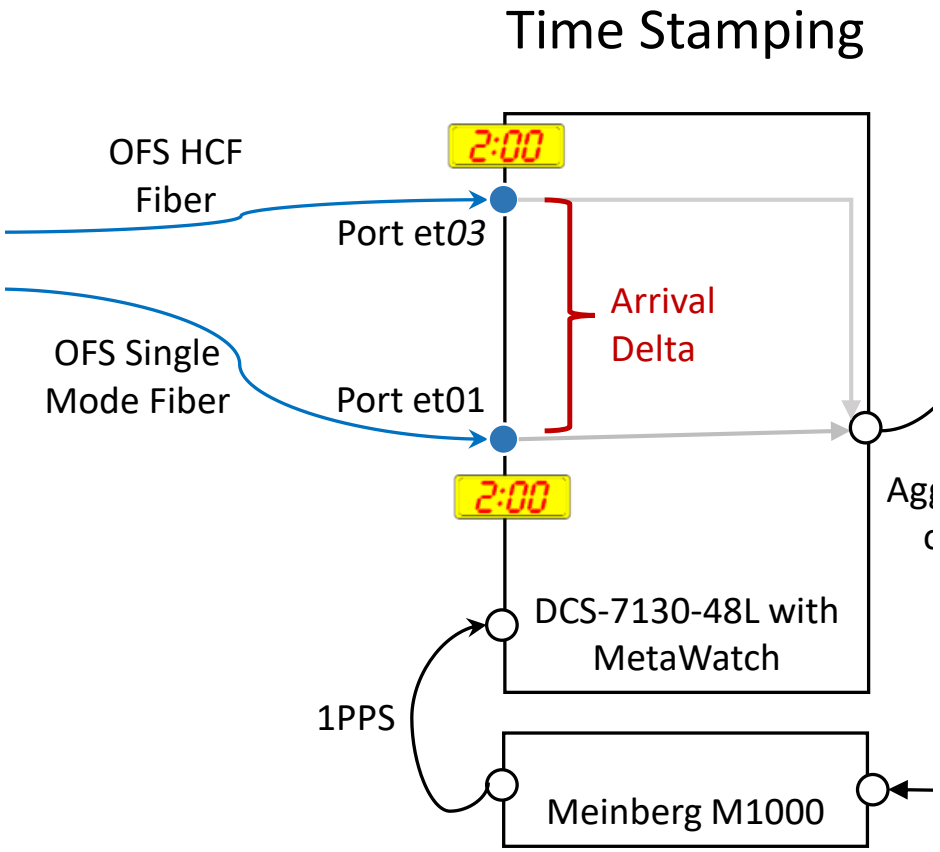
Arrival Delta

- In every test
  - HCF was on port et03
  - SMF was on port et01
- Arrival Delta
  - Time a packet arrived over HCF (et03) subtracted from time packet arrived over SMF (et01)
  - A positive number indicates that HCF has a latency advantage over SMF



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Measurements and error

- Arrival Delta was measured for each replayed packet.
  - Over 70 million observations per fiber length
  - No dropped packets
- Assumed that the latency of each fiber was constant over the test run
- Used the median Arrival Delta across both test runs as our measure of the latency difference.

Measurements and error

- Two potential sources of measurement error
  - Timestamping
  - Length measurement
- For timestamping, we found:
  - Skews were very small (10s of picos)
  - At such a high level of granularity, skews varied from run to run
  - The skews were all non positive, implying whatever advantage we measured for HCF would be understated
- Error in measuring length
  - Always difficult to perfectly straighten and measure cables
  - Difficult to quantify the error in doing so
  - But when we talk results we'll set some boundaries around this error

Latency improvement for 100m cable (nanoseconds)

	Measured value	Estimated Measurement uncertainty
Total latency improvement (median Arrival Delta)	165.4	0 to -0.8
Implied per-meter latency improvement	1.6	< 0.054

Hollow Core Fiber was 1.6 ns faster per meter than single mode fiber

Theoretical vs measured improvement per meter (nanoseconds)

Cable length	Measured improvement	Theoretical improvement	Difference	%
3 meters	4.7	4.8	0.1	1.5%
10 meters	16.6	16.0	-0.6	-3.9%

Key result

Compared to AllWave FLEX Max Optical Fiber (single mode fiber),
AccuCore HCF (hollow core fiber) was
1.6 nanoseconds faster per meter.

Report coming soon

Two topics to discuss

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- FPGA Special Interest Group update

FPGA Special Interest Group

- Initial objectives
  - Facilitate dialog regarding common challenges in FGPA design, development, testing and deployment
  - Articulate industry requirements for FPGA hardware and toolchains where commonalities exist
  - Outline a series of best practices in the development and use of FPGA in financial services
- 8 months in:
  - Have met many times since.
  - Group growing and evolving.

FPGA SIG: Current State

- Grown to 14 active member firms
  - Exchanges, dealers, proprietary trading firms, hedge funds, and others who develop for FPGA
- Two sub-groups created
  - Hardware: working on documenting and prioritizing hardware desires for discussion with FPGA vendors
  - Toolchains: outlining tooling needs for creating continuous integration, simulation, and testing environments to accelerate FPGA developing
- Other initiatives are being discussed

www.STACresearch.com/fpga