OAK RIDGE National Laboratory

Frontier/Crusher Node Performance

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Frontier Training Workshop – February 16, 2023

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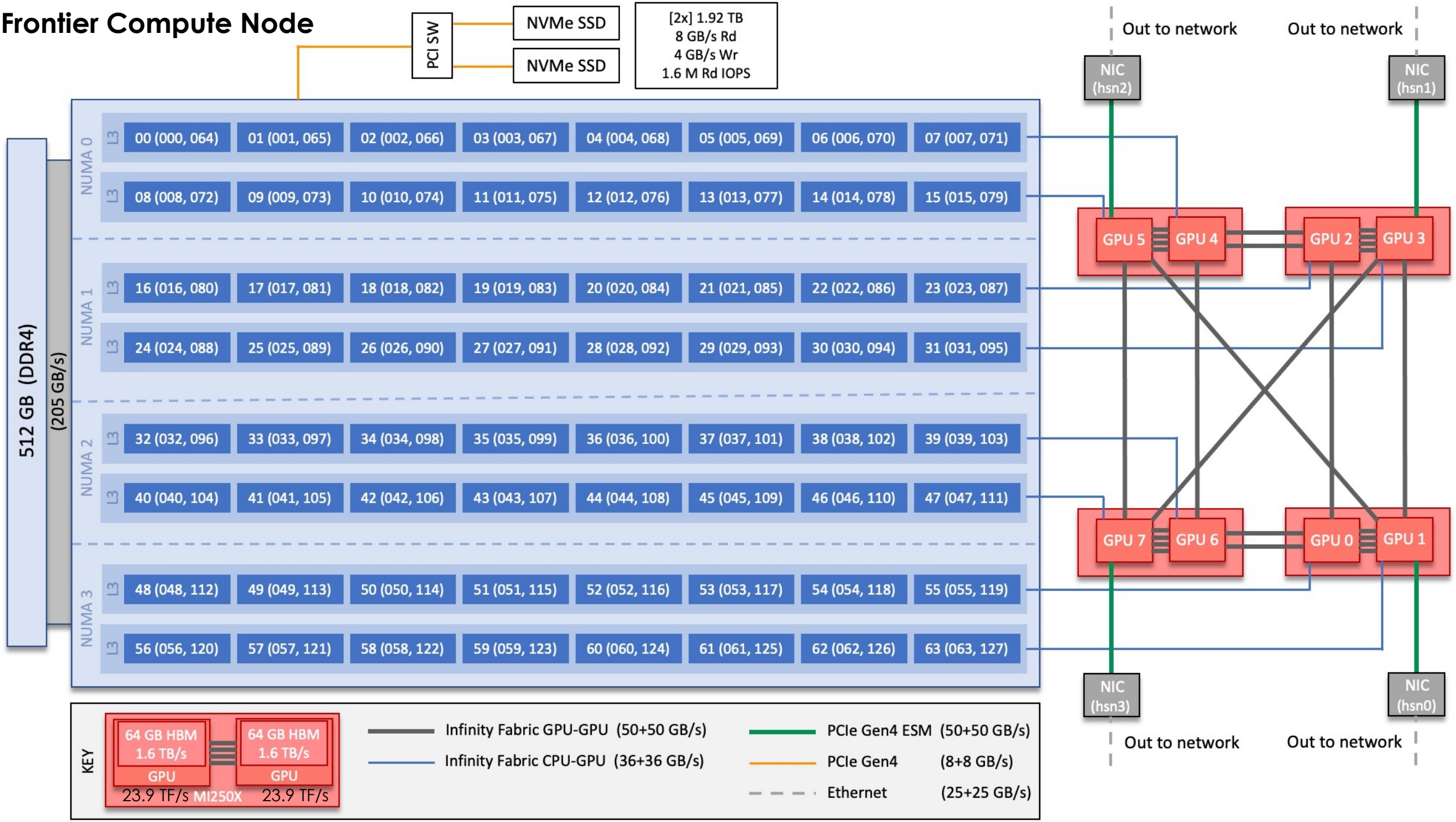
U.S. DEPARTMENT OF ENERGY

Frontier Compute Node



Build and run environment

Unless specified otherwise, the results in these slides were obtained using the following modules on Frontier:

```
$ module -t list
craype-x86-trento
libfabric/1.15.2.0
craype-network-ofi
perftools-base/22.12.0
xpmem/2.5.2-2.4_3.20__gd0f7936.shasta
cray-pmi/6.1.8
cce/15.0.0
craype/2.7.19
cray-dsmml/0.2.2
cray-mpich/8.1.23
cray-libsci/22.12.1.1
PrgEnv-cray/8.3.3
DefApps/default
rocm/5.3.0
craype-accel-amd-gfx90a
```

CPU DRAM Bandwidth

CPU Stream Test

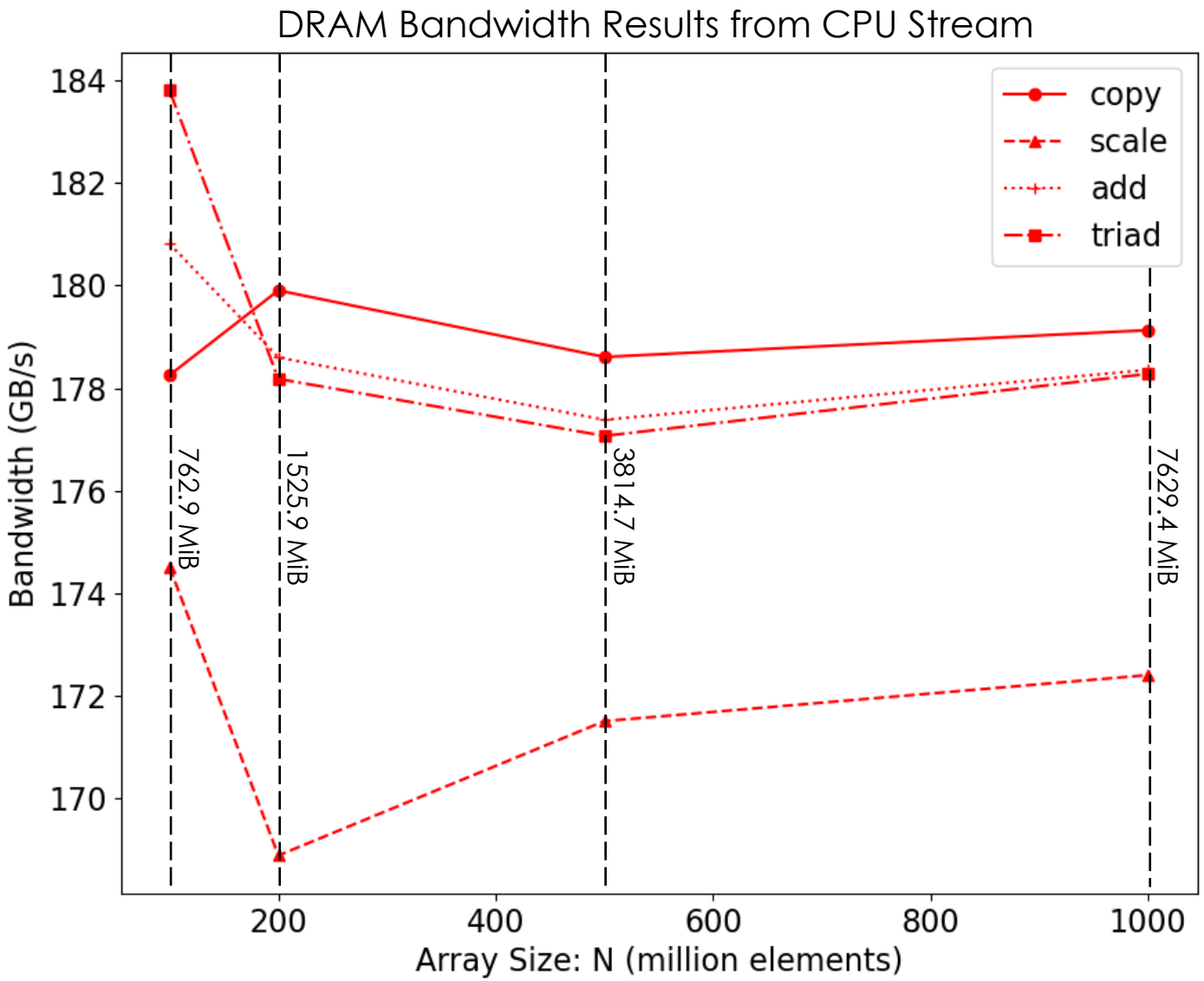
Copy	`A[i] = B[i]`
Scale	`A[i] = n*B[i]`
Add	`A[i] = B[i] + C[i]`
Triad	`A[i] = B[i] + n*C[i]`

- Peak DRAM bandwidth: 205 GB/s
- Observed DRAM bandwidth: 82-90% of peak

NOTES:

```
OMP_NUM_THREADS='8'

Each kernel will be executed 35 times.
The *best* time for each kernel (excluding
the first iteration) will be used to compute
the reported bandwidth.
```



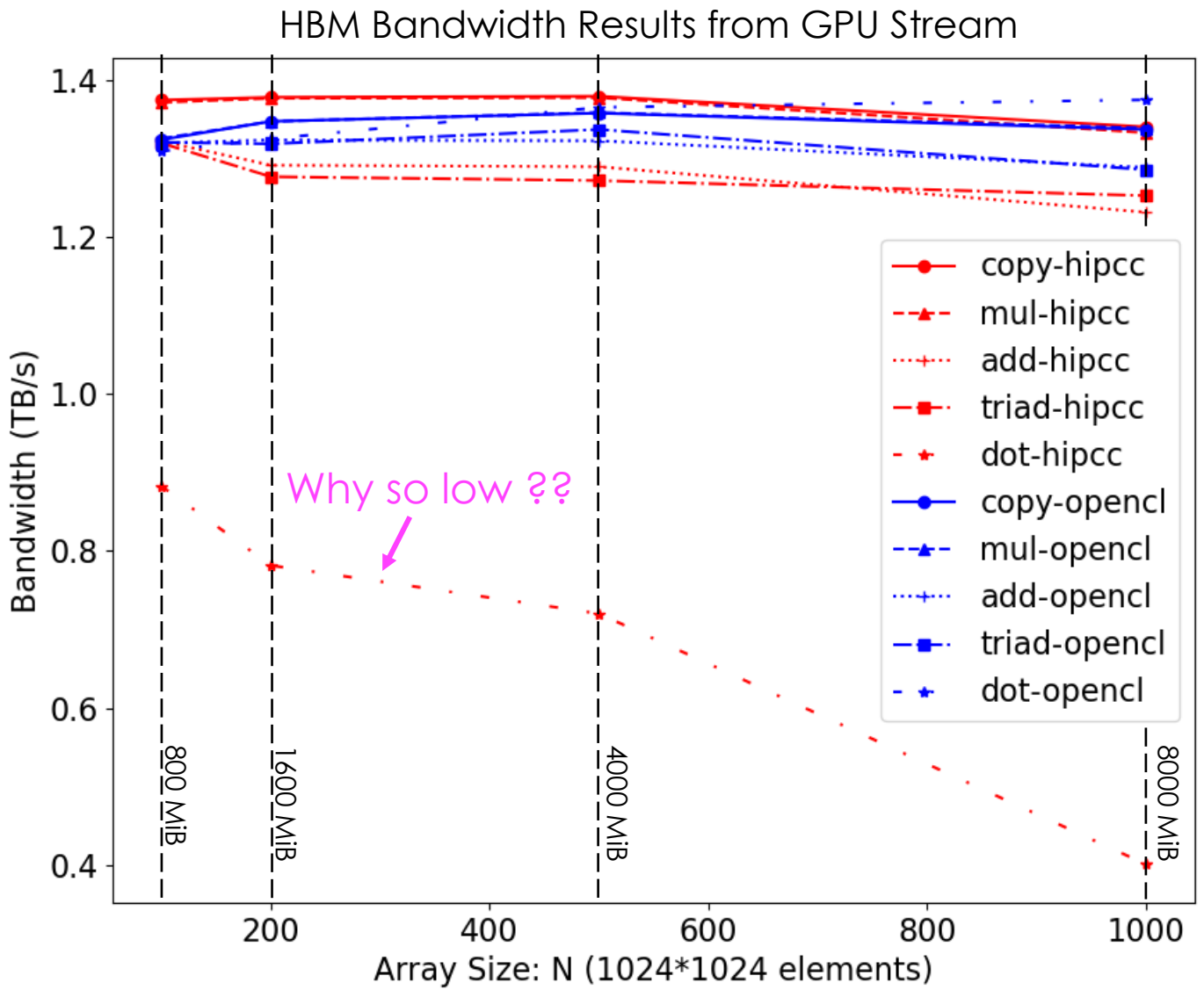
Memory per array is `N*8` bytes
Total memory is `3*N*8` bytes
(where `N` is array size)

GPU HBM Bandwidth

GPU Stream Test

Copy	`A[i] = B[i]`
Scale	`A[i] = n*B[i]`
Add	`A[i] = B[i] + C[i]`
Triad	`A[i] = B[i] + n*C[i]`
Dot	`A[i] = B[i]*C[i]`

- Peak HBM bandwidth: 1.6 TB/s
- Not sure why hipcc dot bandwidth is so low when OpenCL is not…



NOTES:

```
BabelStream
Version: 4.0
Implementation: HIP
Running kernels 100 times
Precision: double
Using HIP device
Driver: 50120531
```

Memory per array is `N*8` bytes
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(where `N` is array size)

GPU HBM Bandwidth

GPU Stream Test

Copy	`A[i] = B[i]`
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- Peak HBM bandwidth: 1.6 TB/s
- Not sure why hipcc dot bandwidth is so low when OpenCL is not…
- Observed DRAM bandwidth: 77-86% of peak

NOTES:

```
BabelStream
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Implementation: HIP
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Precision: double
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```
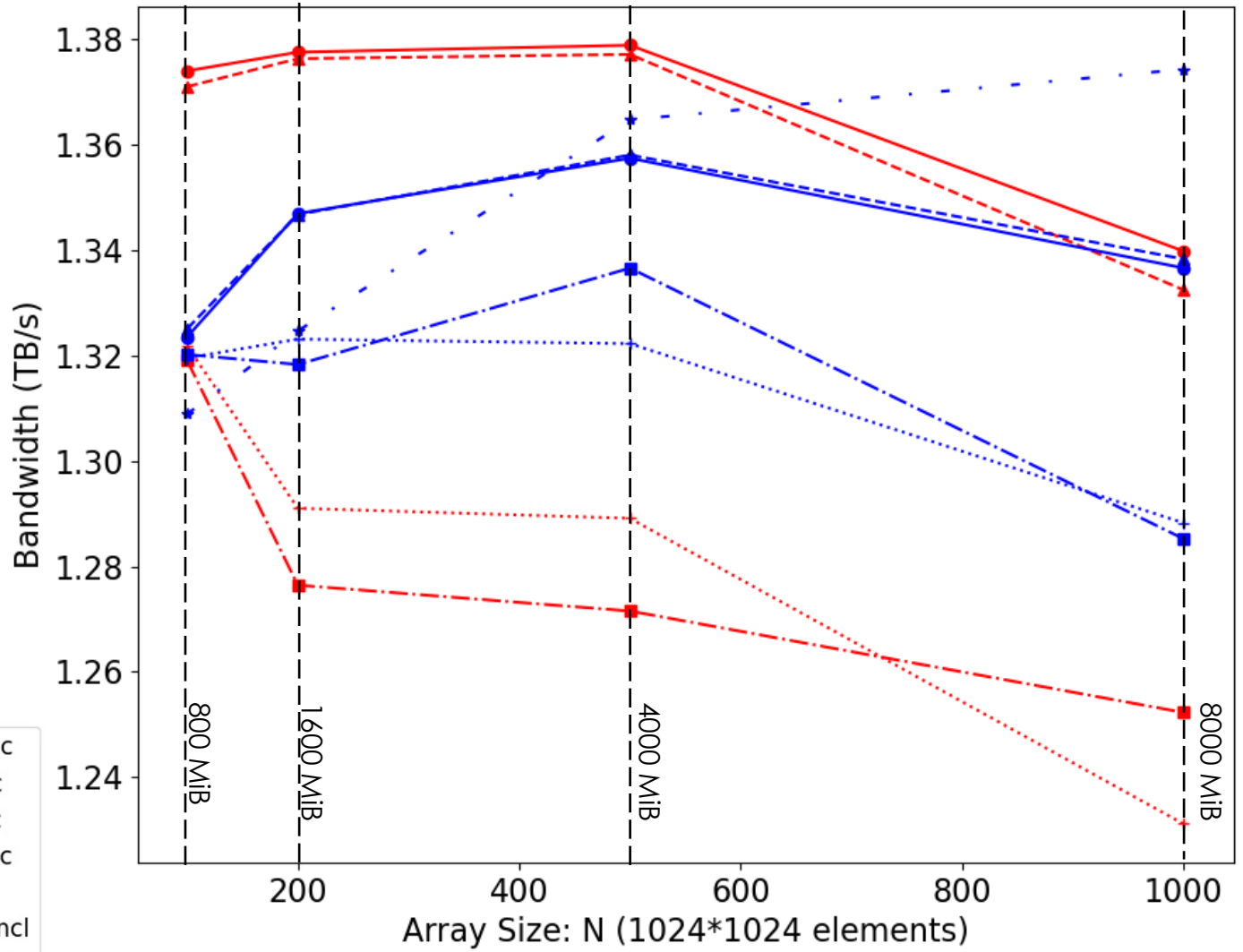

HBM Bandwidth Results from GPU Stream



Memory per array is `N*8` bytes
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(where `N` is array size)

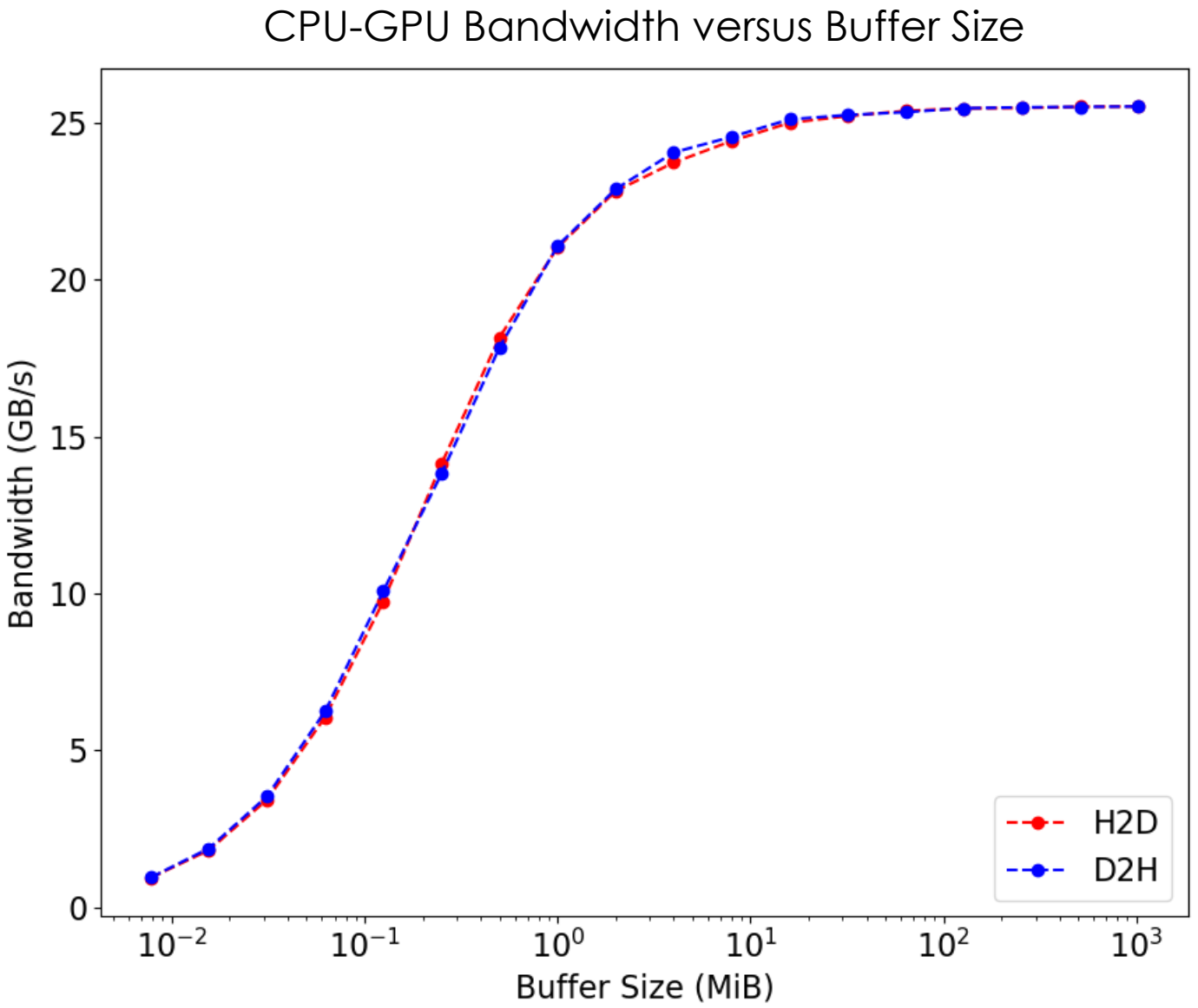
CPU-GPU Bandwidth

https://github.com/tom-papatheodore/h2d_d2h_bandwidth

- Simple bandwidth test
- Measures host-to-device and device-to-host bandwidth using 50 iterations of `hipMemcpy` in each direction.
- Timing measured with `hipEvent`

Peak CPU-GPU bandwidth: 36 GB/s

Max. observed bandwidth: 25.6 GB/s (71% of peak)



GPU-GPU Bandwidth

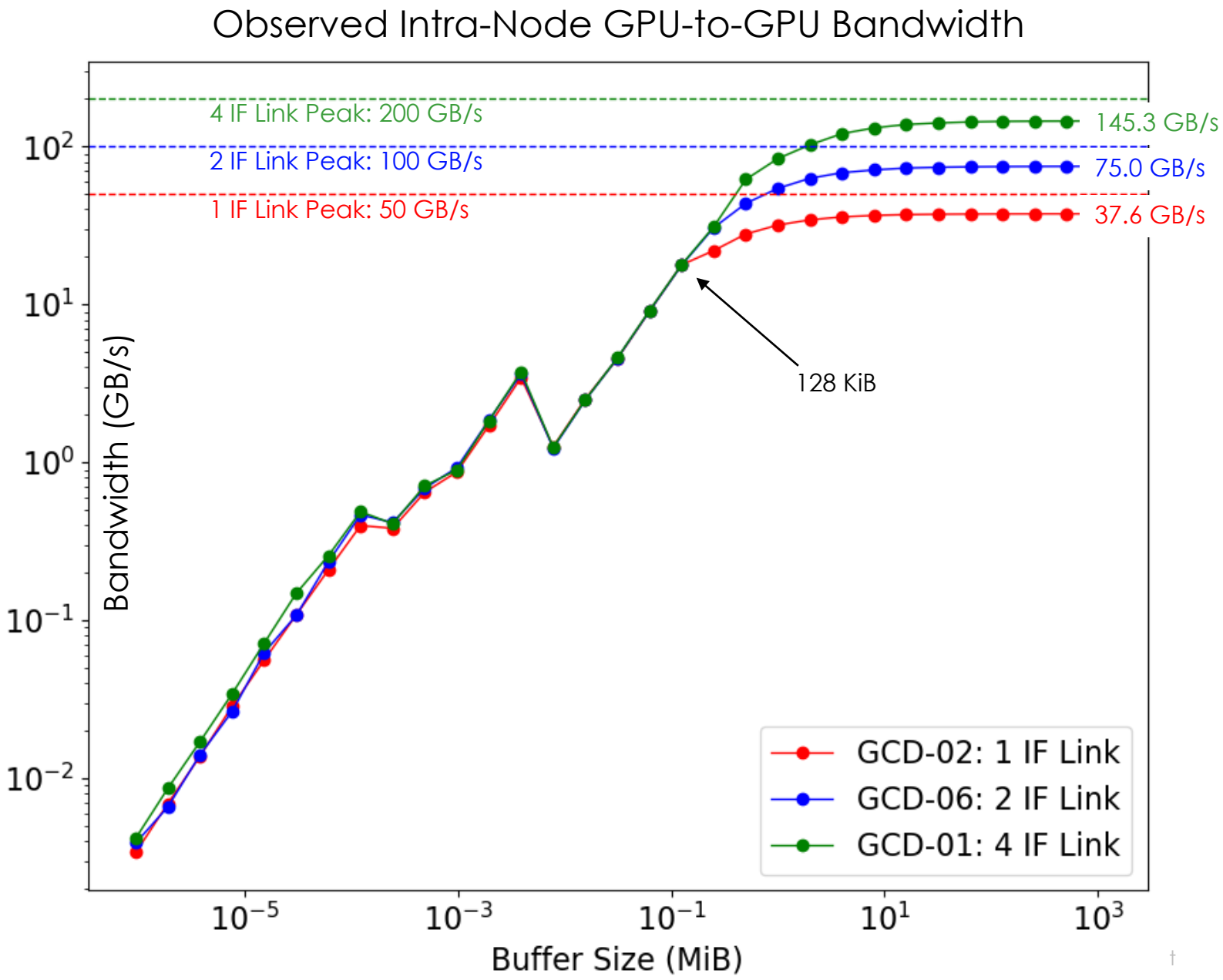
OSU Microbenchmarks: **`osu_bw`**

https://mvapich.cse.ohio-state.edu/benchmarks/

Measure BW between each GPU pair on a node.

Recall from the Frontier node diagram, there can be 1, 2, or 4 InfinityFabric (IF) links between GPUs on a node.

IF Links	BW (GB/s)
1	37.6 (75.2% of peak)
2	75.0 (75.0% of peak)
4	145.3 (72.7% of peak)



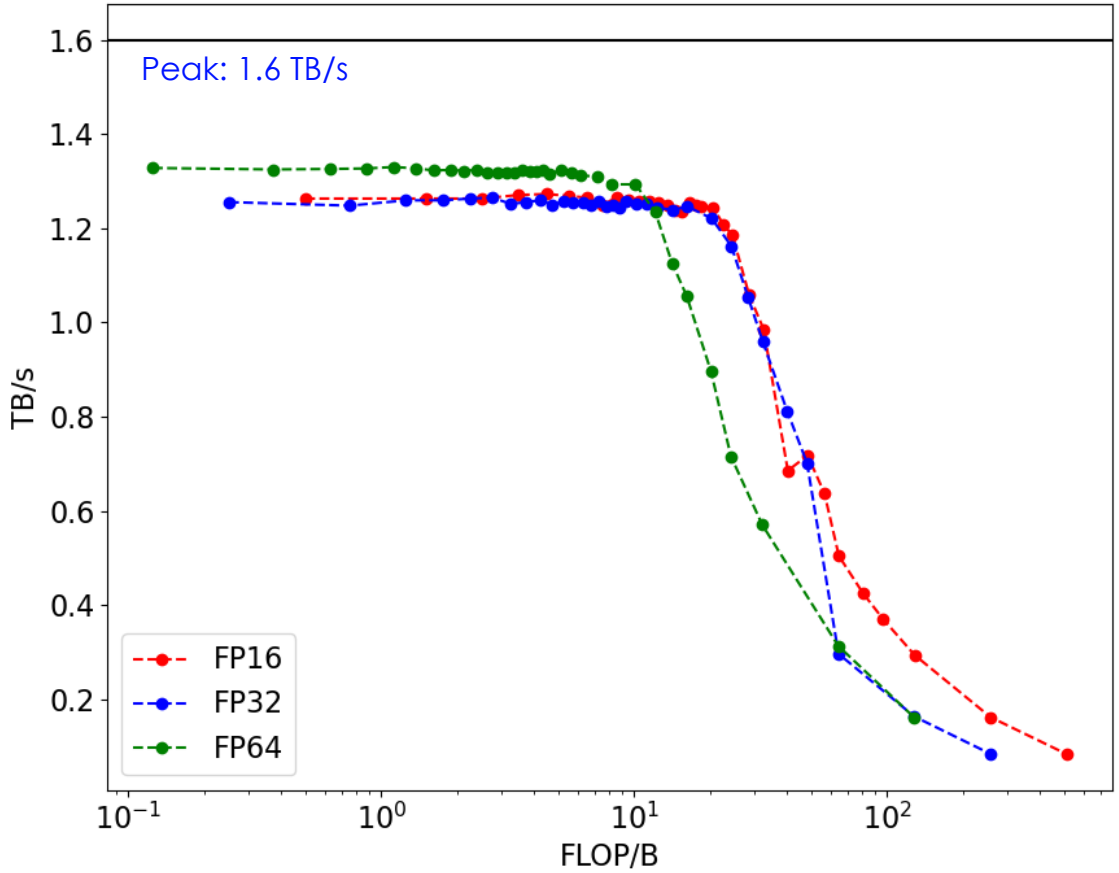
Mixbench

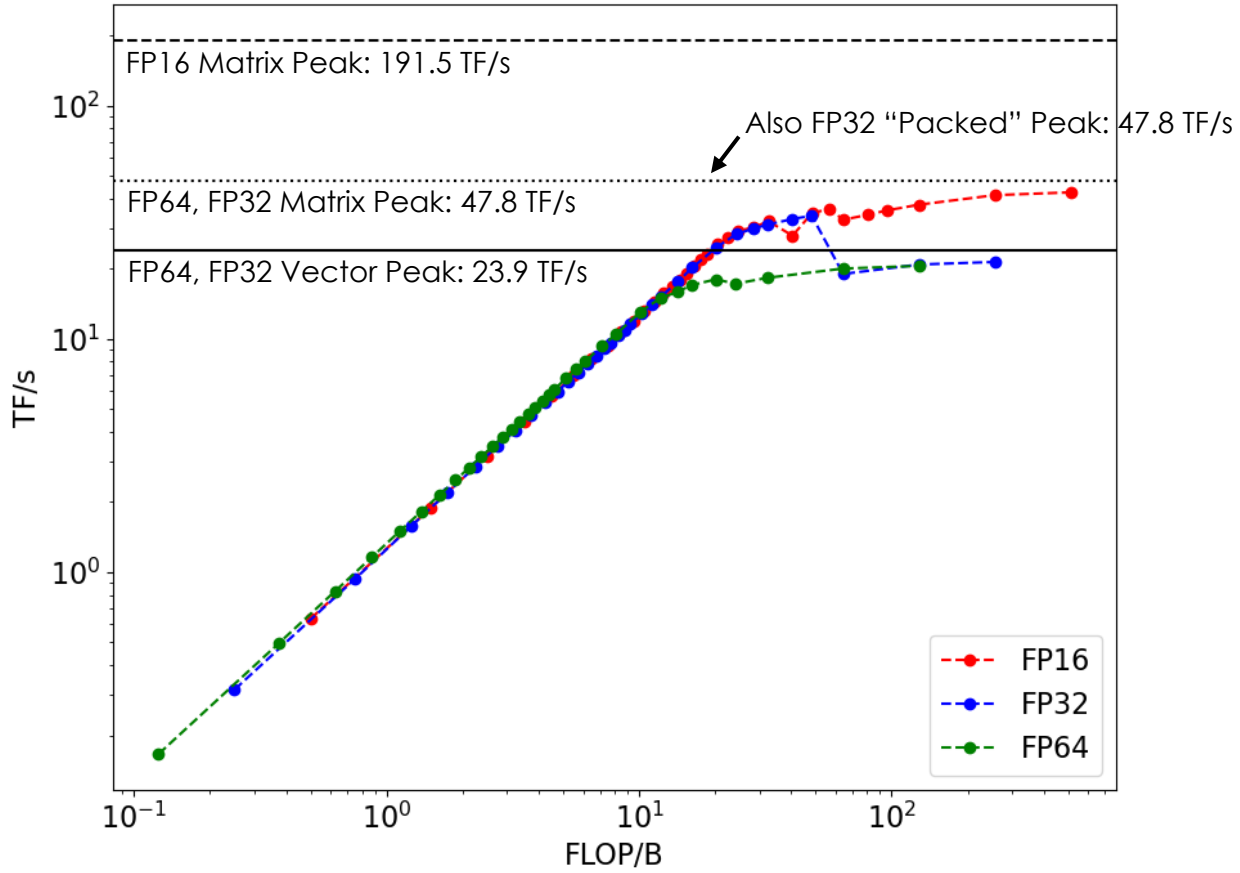
https://github.com/ekondis/mixbench

Measures FLOP/s and GB/s vs FLOP/B

- Buffer size stays fixed while compute iterations increase
- FP64, FP32, and FP16 results

```
---------------------- Device specifications ----------------------
Device:
CUDA driver version: 50322.61
GPU clock rate:      1700 MHz
WarpSize:            64
L2 cache size:       8192 KB
Total global mem:    65520 MB
Total SPs:           7040 (110 MPs x 64 SPs/MP)
Compute throughput:  23936.00 GFlops (theoretical single precision FMAs)
Memory bandwidth:    1638.40 GB/sec
-------------------------------------------------------------------
Total GPU memory 68702699520, free 68702699520
Buffer size:          256MB
Trade-off type:       compute with global memory (block strided)
Elements per thread:  8
Thread fusion degree: 1
```





For details on the peak values and packed FP32 operations: https://www.amd.com/system/files/documents/amd-cdna2-white-paper.pdf

GPU Compute – Dense DGEMM

gpu_xgemm

https://github.com/tom-papatheodore/gpu_xgemm

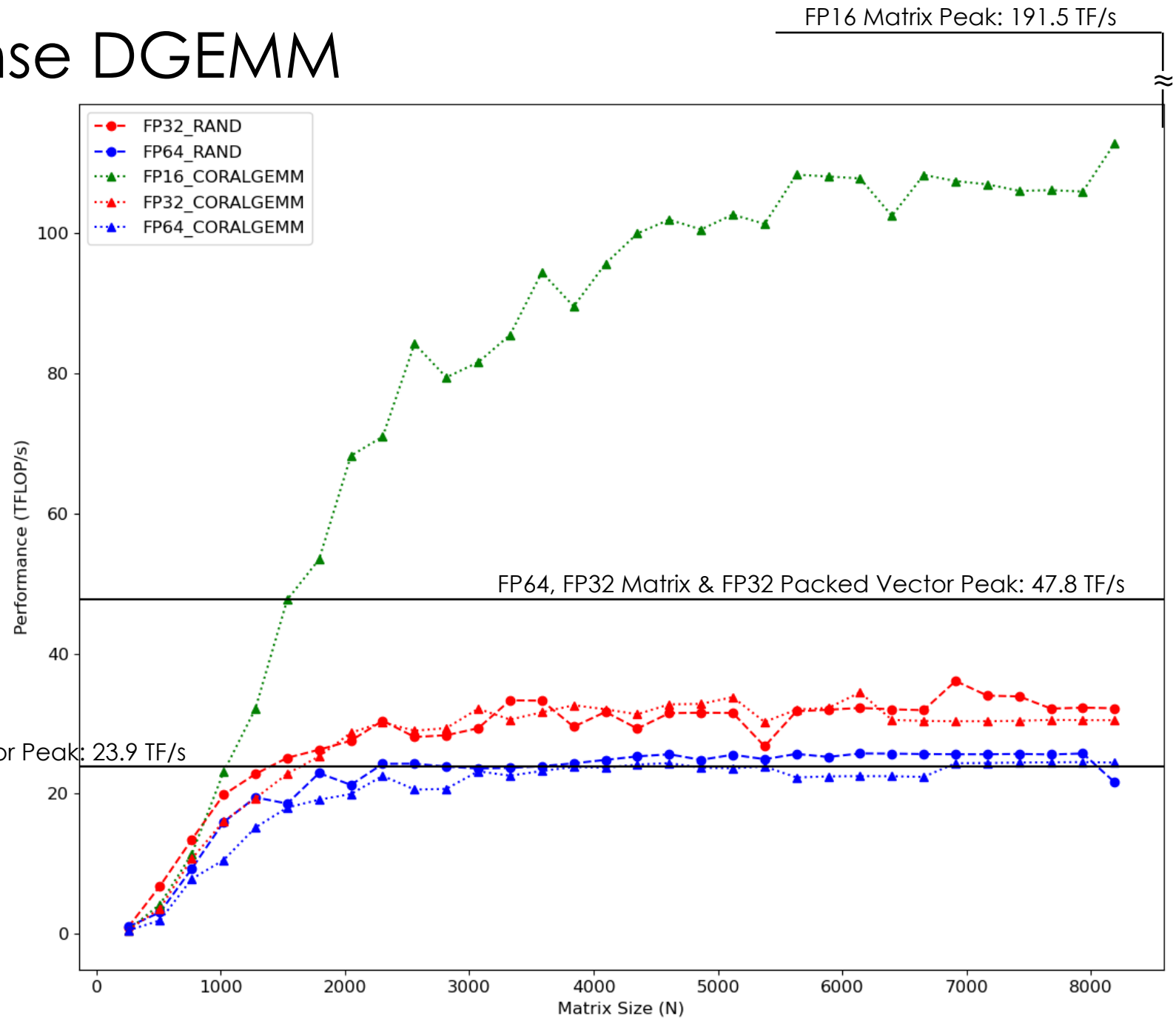
- FP32/64_RAND

CORALGEMM

https://github.com/AMD-HPC/CoralGemm

- FP16/32/64_CORALGEMM

Both of these tests use hipBLAS.



Values for peak obtained from Table 1 of MI250X white paper: https://www.amd.com/system/files/documents/amd-cdna2-white-paper.pdf

Expected Performance (Summit-to-Frontier)

Performance expectations on Frontier relative to Summit

- Is your application GPU-bound or data-transfer-bound?
  - If GPU-bound, is it compute-bound or memory-bound?
    - Compute-bound: compute performance
    - Memory-bound: HBM, HBM bandwidth, L1 cache
    - This is where kernel profiling can be helpful
  - If data-transfer-bound, consider CPU-to-GPU bandwidth in table.

	V100	MI250X (GCD)	MI250X (GCD) / V100	Summit Node	Crusher Node	Crusher Node / Summit Node
Compute performance	~7.8 TF	~23.9 TF	~3.1X	~47 TF	~191 TF	~4.1X
HBM	16 GB	64 GB	4X	96 GB	512 GB	~5.3X
HBM bandwidth	0.9 TB/s	1.6 TB/s	~1.8X	5.4 TB/s	12.8 TB/s	~2.4X
CPU-to-GPU bandwidth	50 GB/s	36 GB/s	~0.7X	300 GB/s	288 GB/s	~0.96X
L1 cache	Up to 128 KB	16 KB	0.125X – 0.5X			
L2 cache	6 MB	8 MB	1.3X			
Network bandwidth				25 GB/s	100 GB/s	4X

Summary

- Regarding raw FP64 FLOP/s, it's *possible* to achieve most of the peak performance out of the MI250X – although this is of course dependent on your application.
  - And in some cases, perhaps even more than expected when libraries take advantage of the matrix cores.
- Observed DRAM bandwidth: 82-90% of peak
- Observed DRAM bandwidth: 77-86% of peak
- Observed CPU-GPU bandwidth: 71% of peak
- Observed GPU-GPU bandwidth: 72-75% of peak
- When comparing Frontier results to Summit (or another system), it's important to understand how all the differences in speeds-and-feeds affect **your application**.
- Other considerations:
  - Warp size is 64 on MI250X, but 32 on V100.
  - L1 cache is smaller on MI250X
  - Register usage can affect performance
  - HW atomics must be enabled to use: https://docs.olcf.ornl.gov/systems/crusher_quick_start_guide.html#floating-point-fp-atomic-operations-and-coarse-fine-grained-memory-allocations
  - GPU page migration w/managed memory must be enabled to use: https://docs.olcf.ornl.gov/systems/crusher_quick_start_guide.html#enabling-gpu-page-migration

Questions?

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