Recent Advances in UCX for AMD GPUs

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Outline

- New ROCm features in UCX 1.15
- v2 protocols status update
- Non-temporal buffer transfers on “Zen 3”/”Zen 4” architectures
- Summary

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ROCm support in UCX

- **ROCm/COPY**: data transfer between host and device memory within a single process
- **ROCm/IPC**: data transfer between device memories of different processes on the same node
- GPUDirect RDMA for communication between processes on different nodes
- Memory type detection of ROCm memory
- Memory hooks for ROCm memory allocations

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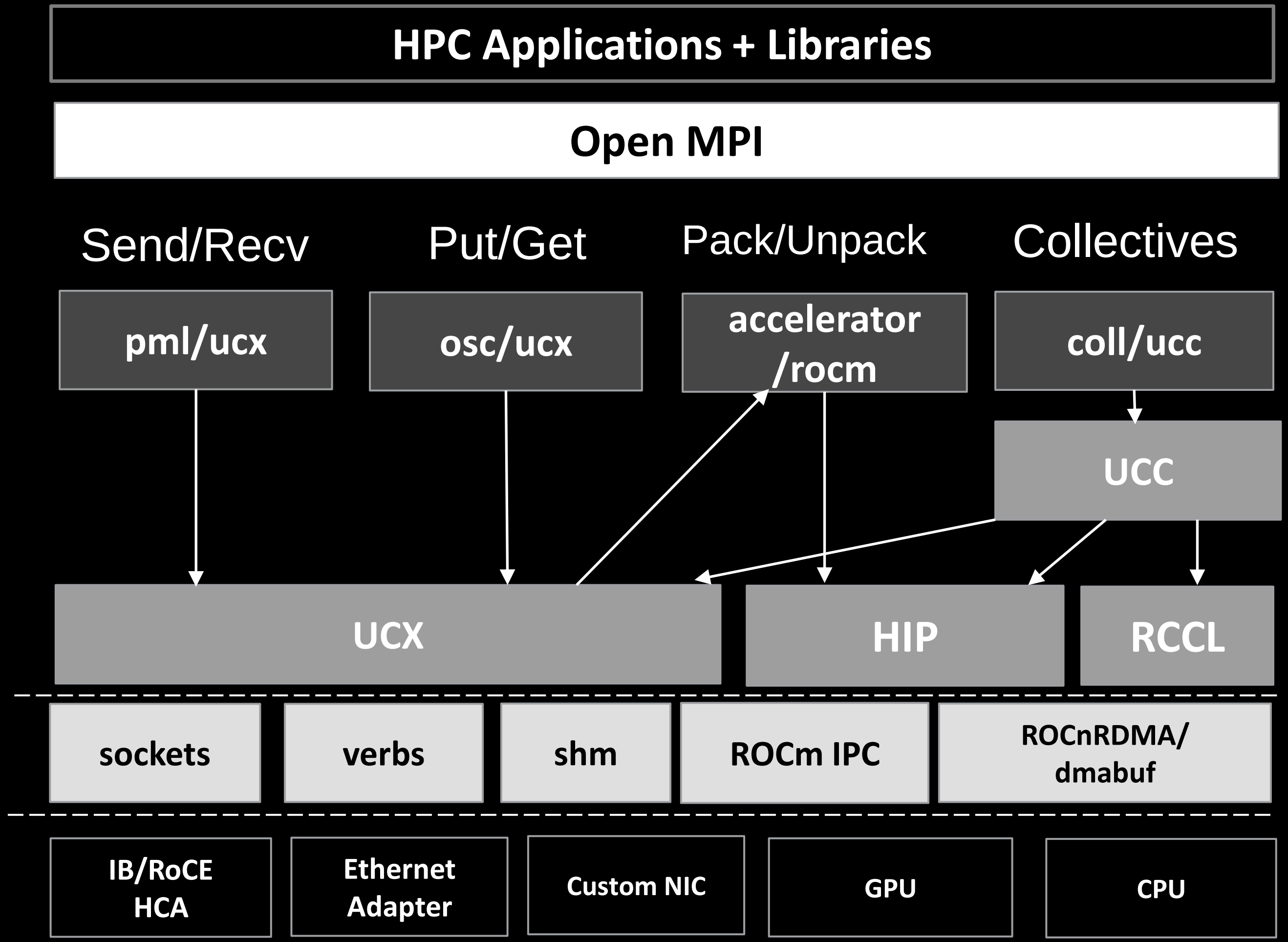
ROCm Aware Open MPI Software Stack with UCX and UCC

- Recommended software stack for InfiniBand and RoCE networks
- Most stable and best tested configuration



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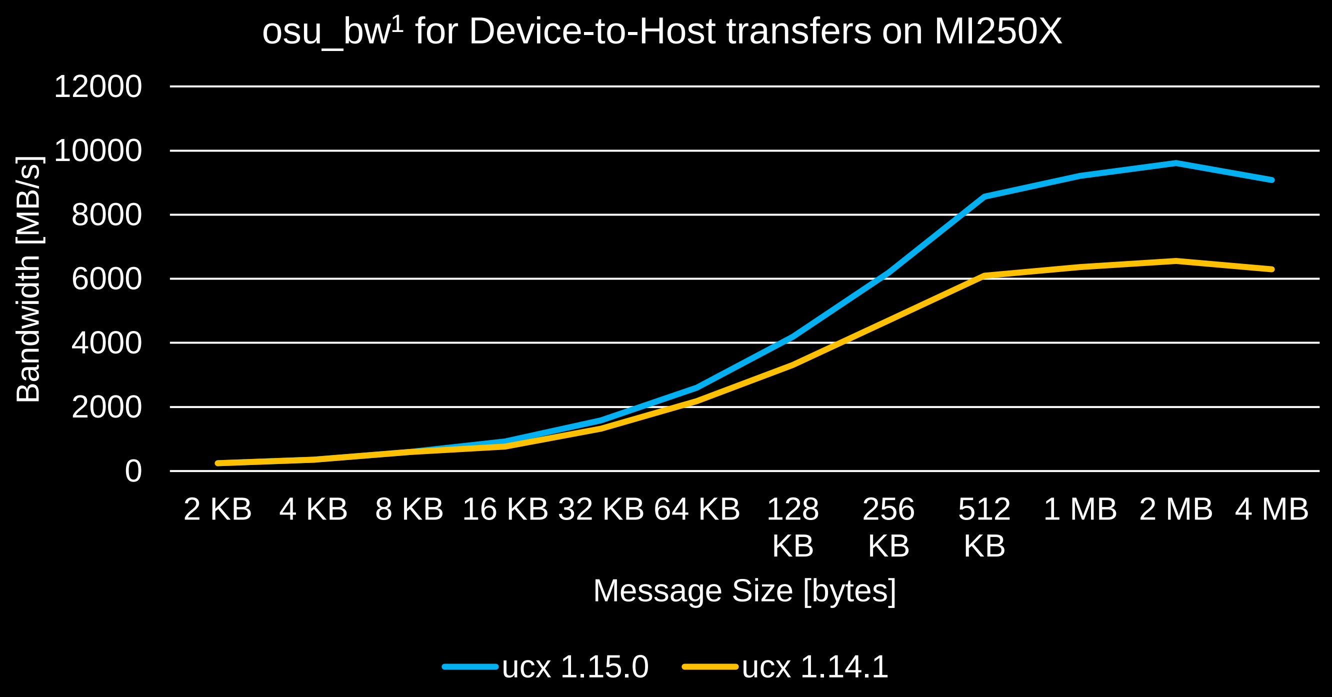
New ROCm Features in UCX 1.15

Asynchronous ROCm/copy zero-copy operations

- Allows to overlap multiple stages in some protocols
- Potential to improve device-to-host and host-to-device transfers

- Unified progress function for ROCm/copy and ROCm/ipc components



[1] OSU Benchmark Suite https://mvapich.cse.ohio-state.edu/benchmarks/ (BSD License).

New ROCm Features in UCX 1.15

dma-buf support for ROCm devices

- dma-buf: Linux kernel subsystem providing a framework for sharing buffers across multiple devices
  - For example, RDMA capable network adaptor accessing a GPU device buffer
- Long-term replacement for the ROCnRDMA kernel component
- ROCm release 5.6 introduced functionality to export a device buffer for dma-buf sharing

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New ROCm Features in UCX 1.15

dma-buf support for ROCm devices

- Three components required to use dma-buf-based sharing for RDMA capable NICs
  - ROCm version with support for exporting dma-buf handle (`hsa_amd_portable_export_dmabuf()`)
  - Version of the libibverbs that supports dma-buf-based memory registration (`ibv_reg_dmabuf_mr()`)
  - Linux kernel with certain features enabled (CONFIG_DMABUF_MOVE_NOTIFY, CONFIG_PCI_P2PDMA)

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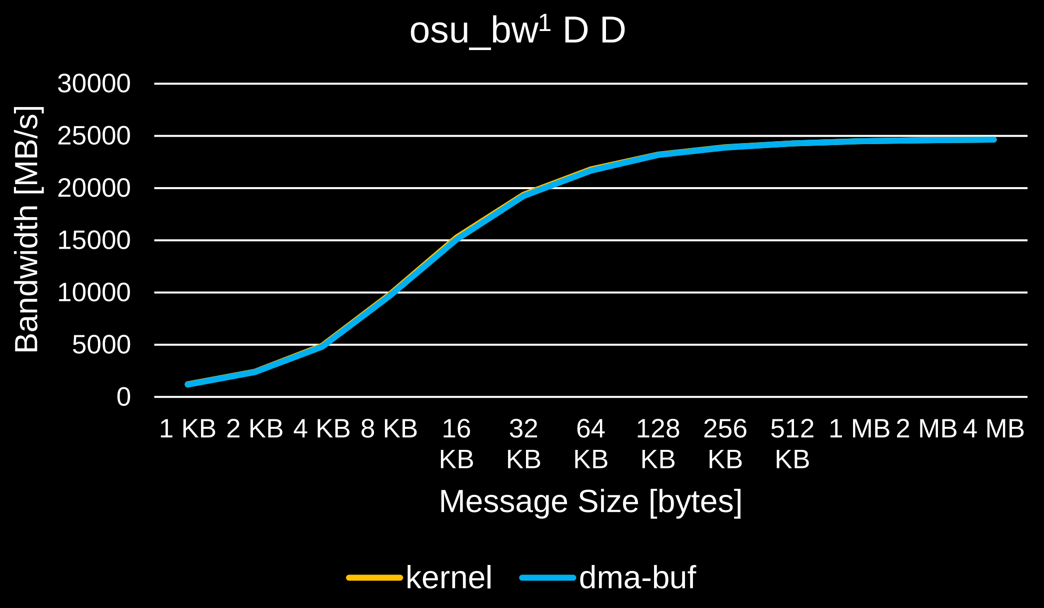
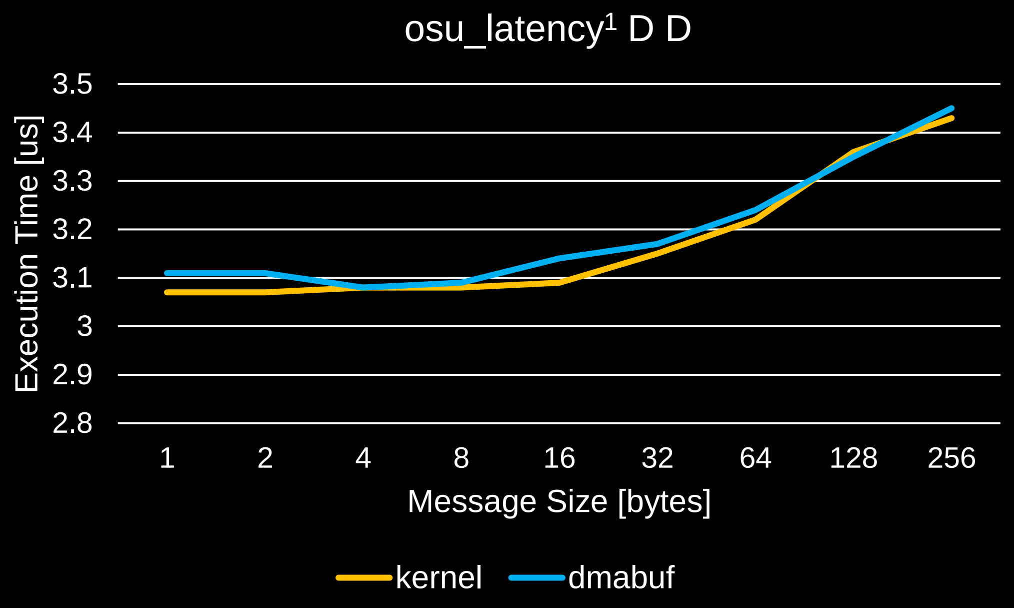
New ROCm Features in UCX 1.15

dma-buf vs. ROCnRDMA kernel component

- 200Gb InfiniBand, mofed 5.9-0.5.6.0
- MI210 GPUs
- UCX 1.15.0, Open MPI 5.0, osu benchmarks 7.2.0





[1] OSU Benchmark Suite https://mvapich.cse.ohio-state.edu/benchmarks/ (BSD License).

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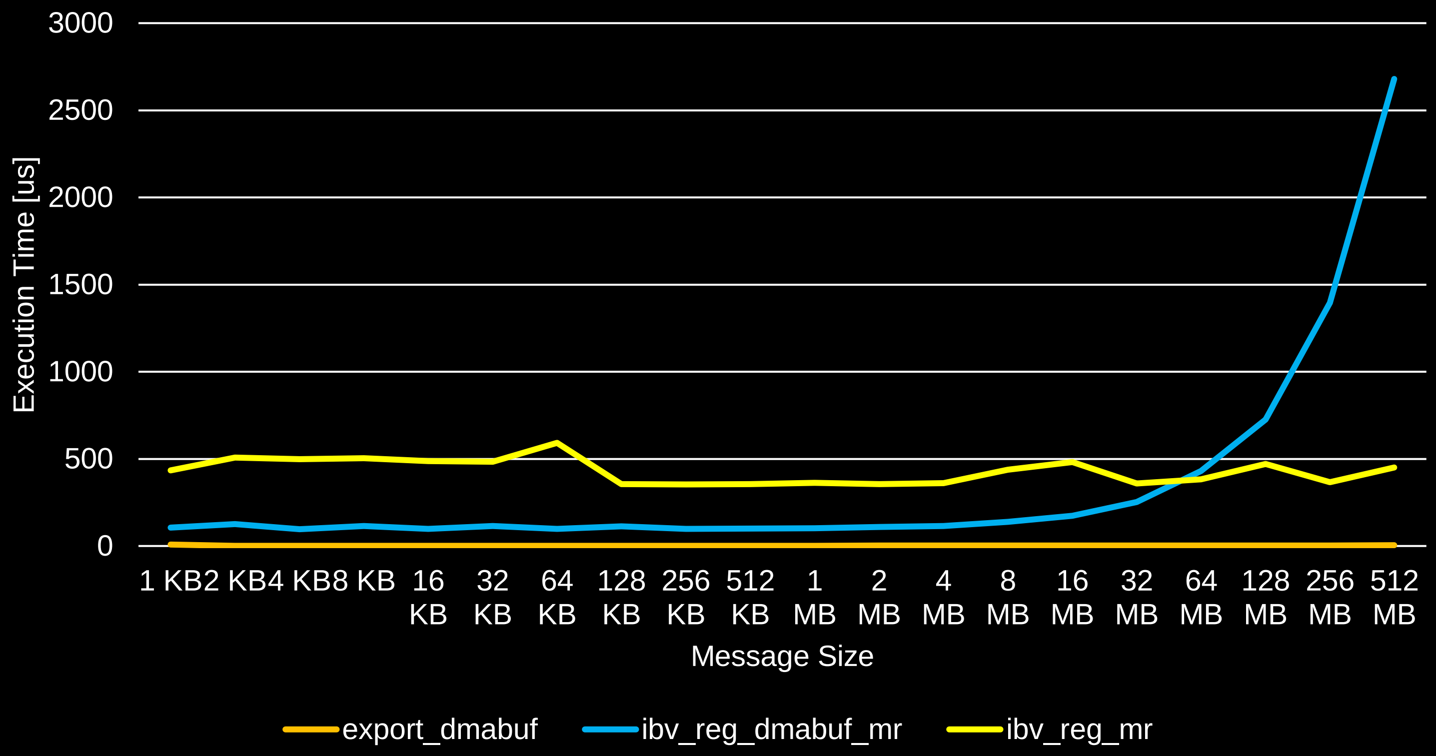
New ROCm Features in UCX 1.15

- Dma-buf vs. kernel component: registration costs
  - Ubuntu 22.04 with custom compiled Linux kernel 5.15
  - ROCm 5.7.1
  - mofed 5.9-0.5.6.0



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New ROCm Features in UCX 1.15

- Setting device_id for AMD GPUs
  - PCIe BDF for each GPU stored and can be used (e.g., for distance calculations)
  - Easier identification in debugging output
- Added logic for GPU assignment of ROCm memory domains
  - UCX uses internally the ROCm runtime layer functionality
  - Runtime layer does not have the notion of ‘current device’ that has been set (e.g. hipSetDevice())
  - Revamped logic allows to determine current device for some scenarios (interception of device allocation using memory hooks, HIP_VISIBLE_DEVICES)

v2 Protocols Status Update

- Intra-node correctness for ROCm device buffers ✓
- Inter-node correctness for ROCm device buffers ✓
- Intra-node performance for ROCm device buffers
  - Point-to-point ✓
  - Collectives (✓) some overhead (20-50%) observed for short messages compared to ucx 1.15 for some collective operations
- Inter-node performance for ROCm device buffers
  - Point-to-point (✓)
    - RoCE ✓
    - IB still under investigation
  - Collectives
    - RoCE ✓
    - IB still under investigation

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Non-Temporal Buffer Transfer

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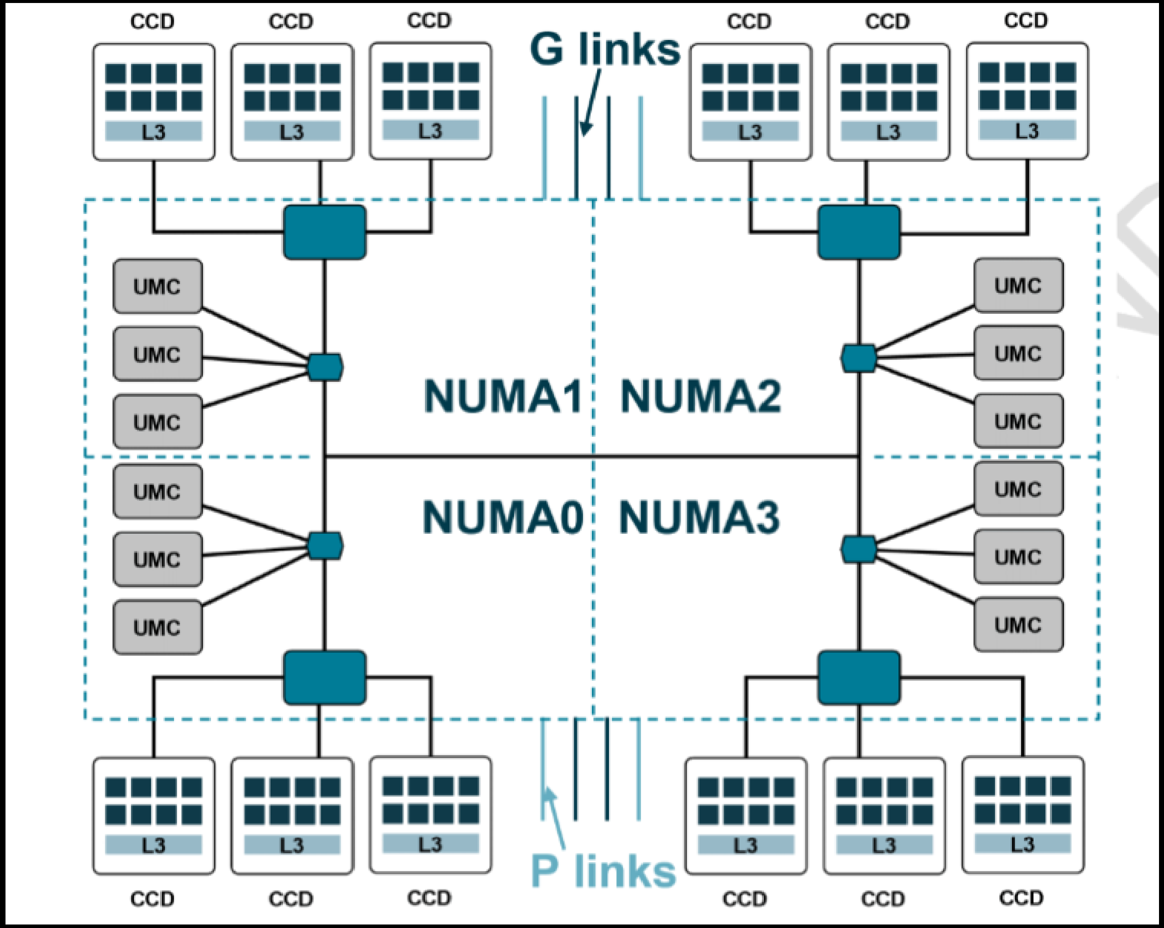
Hybrid MPI Applications on “Zen 3”/”Zen 4”

- Processors based on AMD’s “Zen 3”/”Zen 4” architecture typically organize CPU cores into clusters of eight or more that share a common L3 cache(CCD).
- Hybrid MPI applications often employ 'n-ranks X m-threads' configuration

  n <= Number of unified L3caches in system
  m >= Number of cores that share a common L3cache

  For example: 16 ranks X 8 OpenMP threads combination on a single “Milan” node
- Non-temporal buffer transfers try to improve the data transfer speed/application performance for such hybrid workloads.
- Communication libraries use copy-in, copy-out (shared memory) or single copy mechanisms to move data between ranks.
- Only UCX PML is considered for optimization here: https://github.com/openucx/ucx/pull/9408



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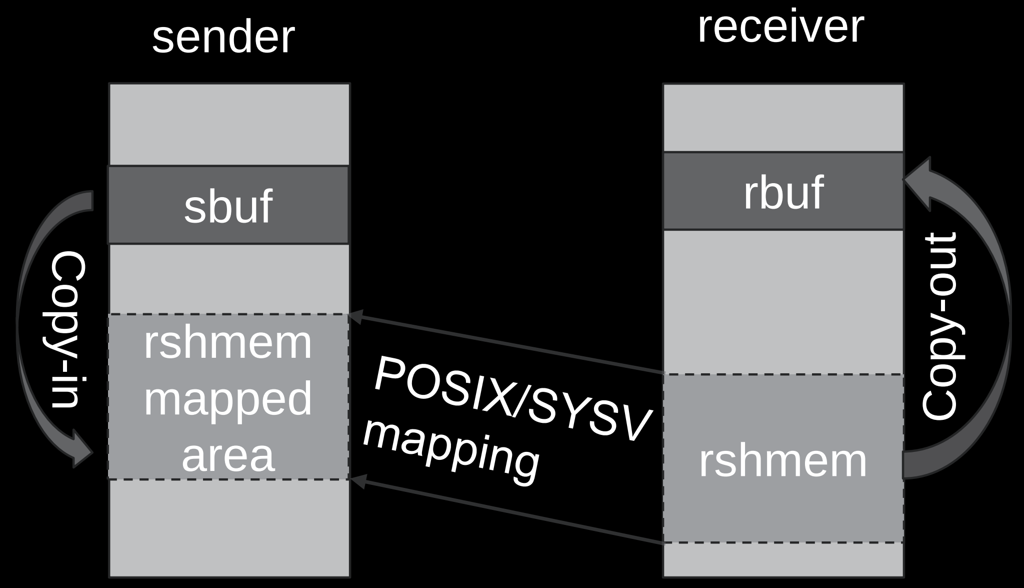
Handling UCX Copy-in, Copy-out (CICO)

- Non-temporal buffer transfer targets the hybrid workloads where sender and receiver do not share a common L3 cache (i.e., pinned to two different CCD)
- Use two distinct mechanism in place of glibc's memcpy for both copy-in and copy-out
  - New Copy-in routine:
    - Copy sender's buffer to receiver's shared memory
    - Use non-temporal store instead of normal store instructions while storing the data to shared memory destination
  - New Copy-out routine:
    - Copy from shared memory to receiver's buffer
    - Use 'Loads with PREFETCHNTA' instead of normal load instruction while loading from shared memory



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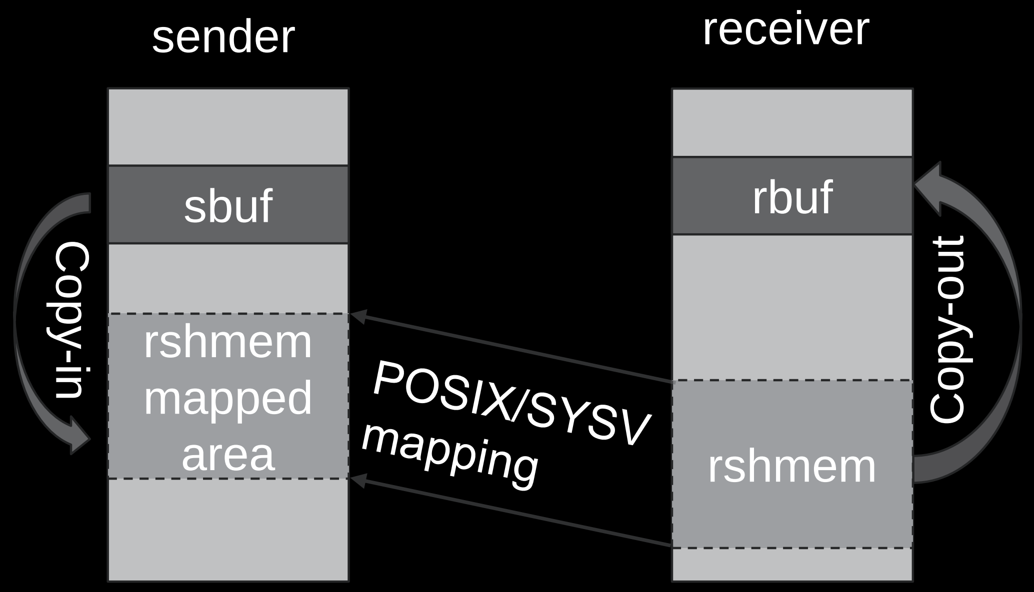
Handling UCX Copy-in, Copy-out (CICO)

- Advantages of using non-temporal load and store instruction
  - Reduces data transfer latency by circumventing cache-to-cache data transfers, which tend to be slower, when ranks/processes are situated in different CCD
  - Reduces the cache pollution, tends to keep only the application buffer in the caches



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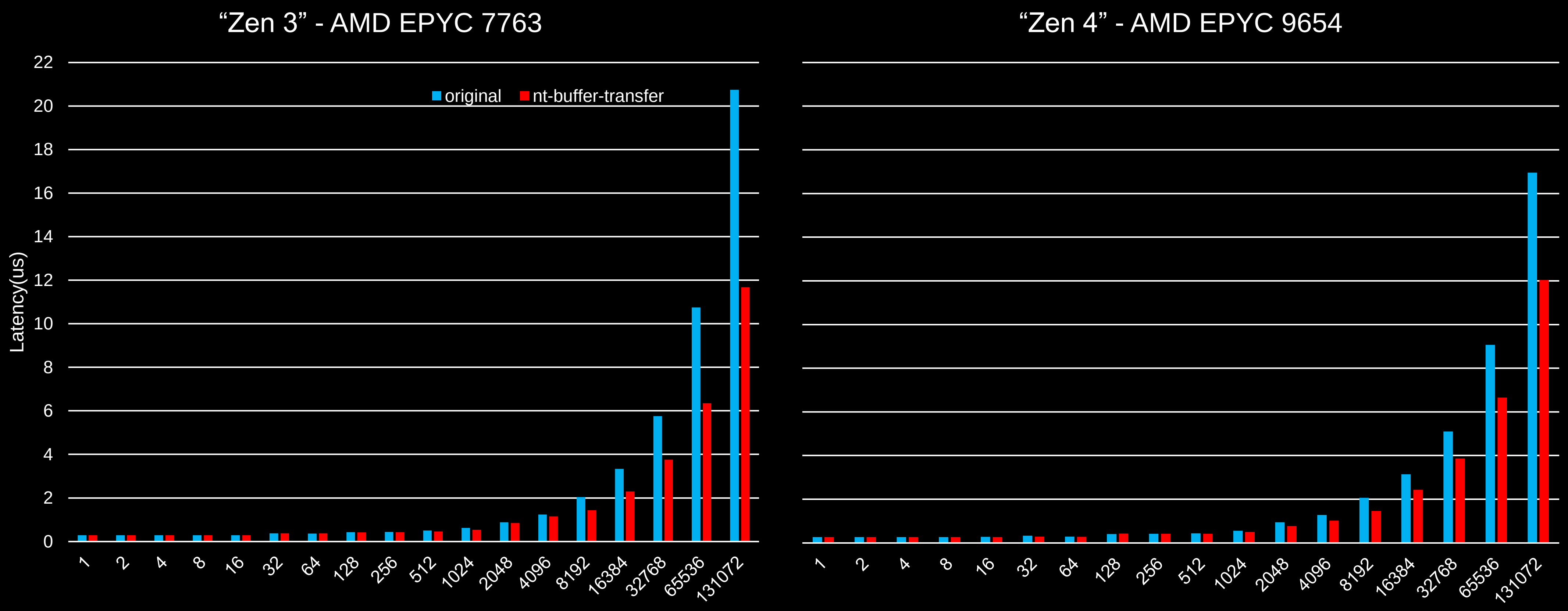
CICO osu_latency[1] Benchmark Results (map-by l3cache)



Gain: "Zen 3" up to 43 % @128 KB, "Zen 4" upto 28 % @128 KB

[1] OSU Benchmark Suite https://mvapich.cse.ohio-state.edu/benchmarks/ (BSD License).

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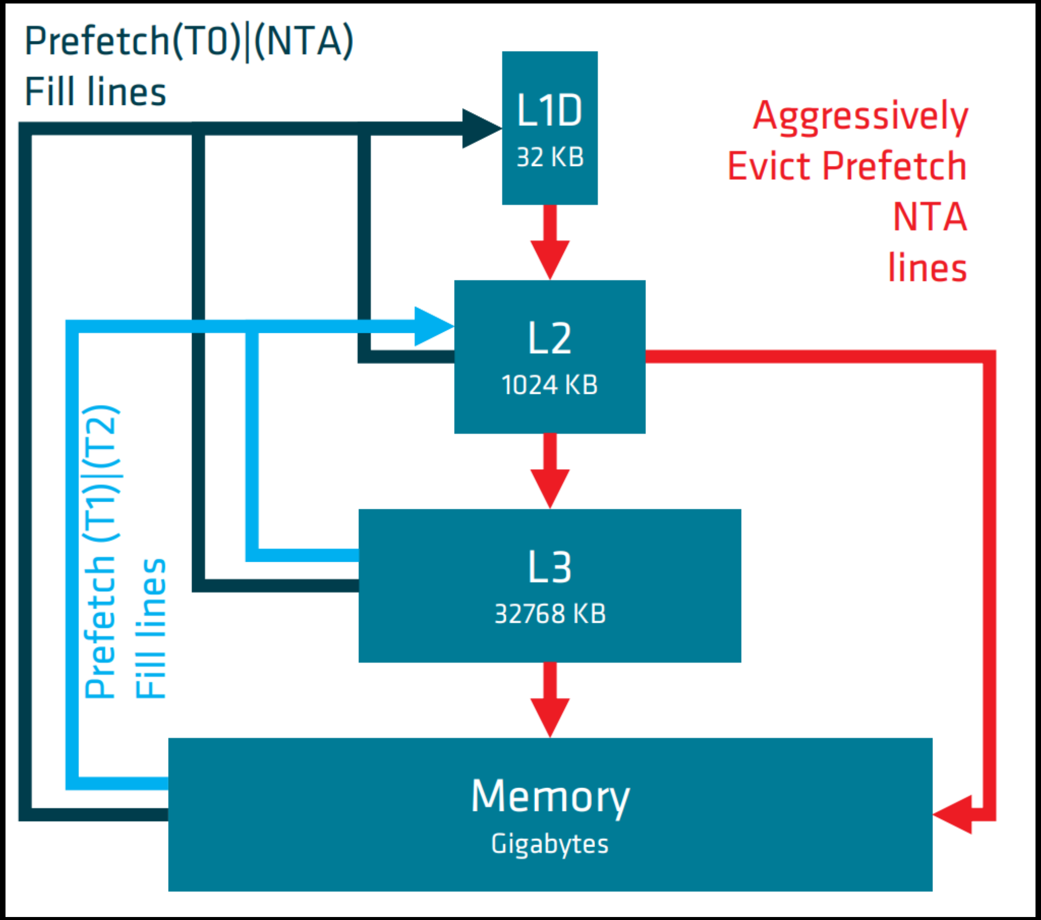
UCX Single Copy (SCOPY) Optimization

- Only xpmem is considered as it is the only single copy mechanism that uses memcpy in userspace
- The new method uses ‘loads with PREFETCH NTA’ instead of normal load instructions while copying from the sender
- It reduces cache pollution in the receiver
- The cache line bouncing effect in the sender is reduced for sizes less than L3 cache size



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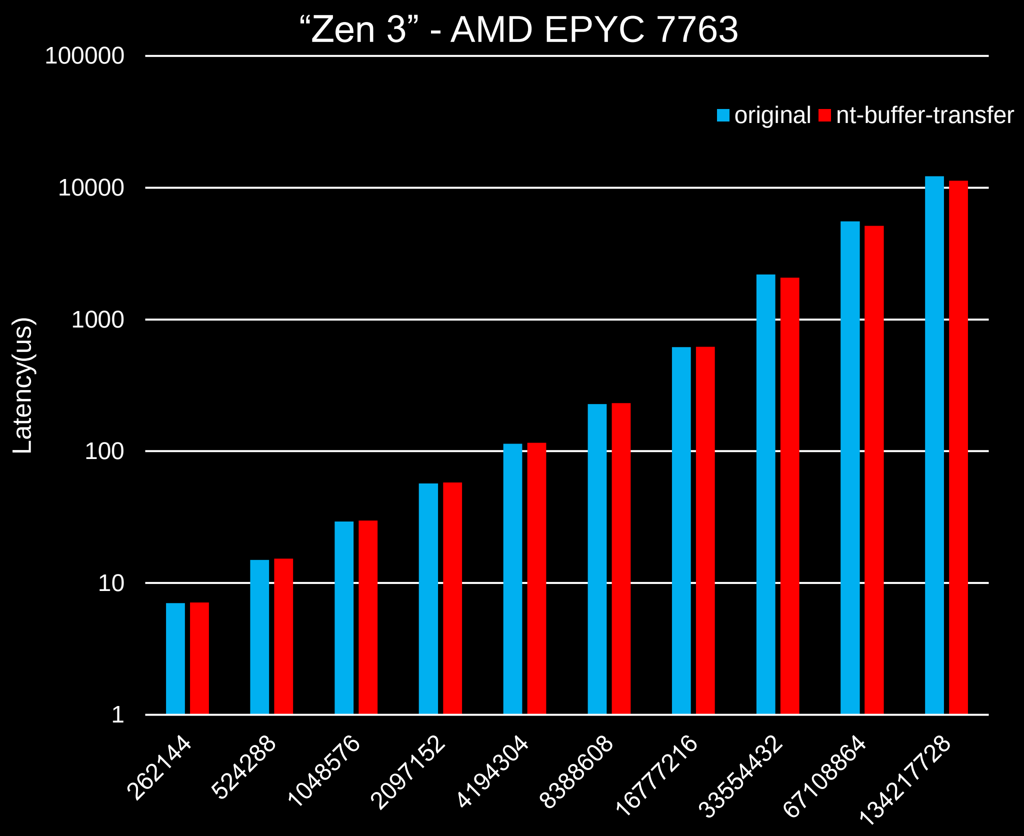
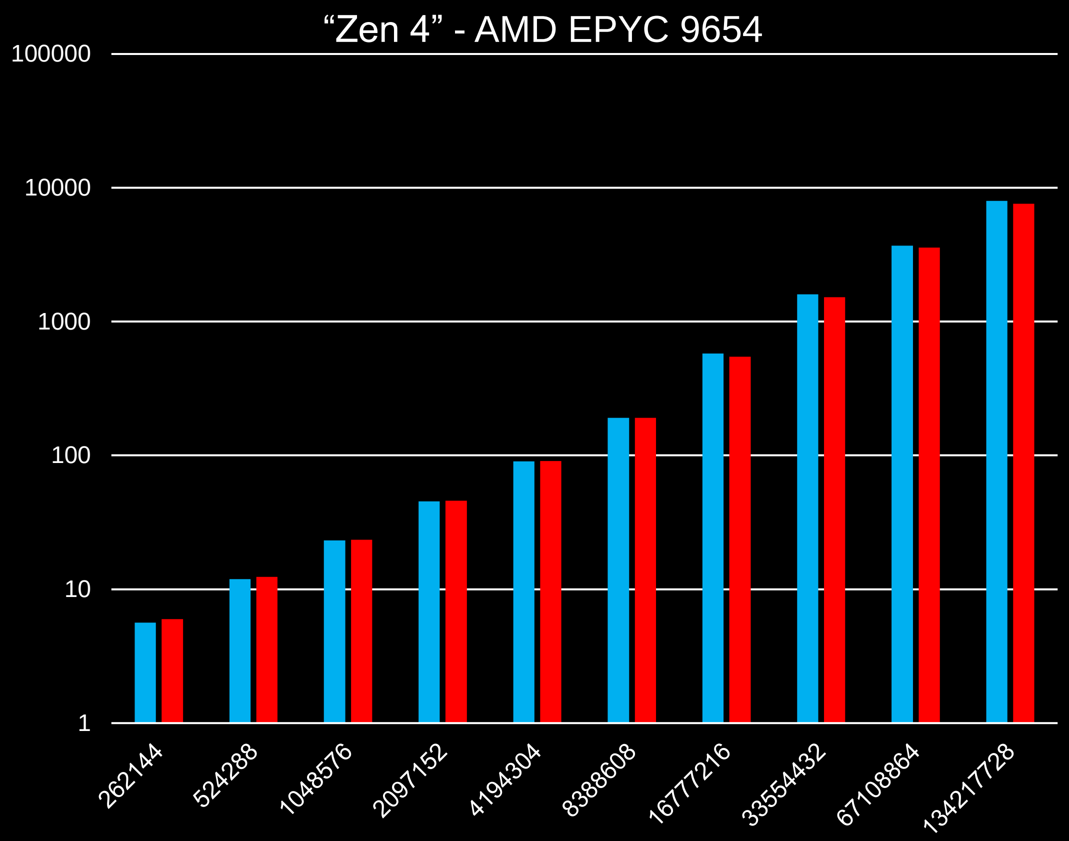
SCOPY osu_latency[1] Benchmark Results (map-by l3cache)





Gain: "Zen 3" 5-7 % for larger sizes, "Zen 4" 4-5 % for larger sizes

[1] OSU Benchmark Suite https://mvapich.cse.ohio-state.edu/benchmarks/ (BSD License).

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