urdma: A Remote Direct Memory Access verbs provider using DPDK

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Agenda

- Background
- Implementation
- Evaluation
- Summary

Background

Background: RDMA (Remote Direct Memory Access)

- Message-oriented
- “Zero-copy”: direct transfer between remote application virtual memory regions with no intermediate data copies (on the hosts)
  - Requires application to pre-register memory
- Kernel bypass: userspace application has direct access to network adapter
- Asynchronous: data transfers occur in parallel with application threads, using OpenFabrics Alliance (OFA) **verbs API**
- Transfer operations
  - SEND/RECV
  - RDMA WRITE: push data to remote memory region
  - RDMA READ: pull data from remote memory region
- Data structures: Queue Pair (QP), Completion Queue (CQ)
- Standards: InfiniBand, RoCE, **iWARP**

urdma: Userspace Software RDMA

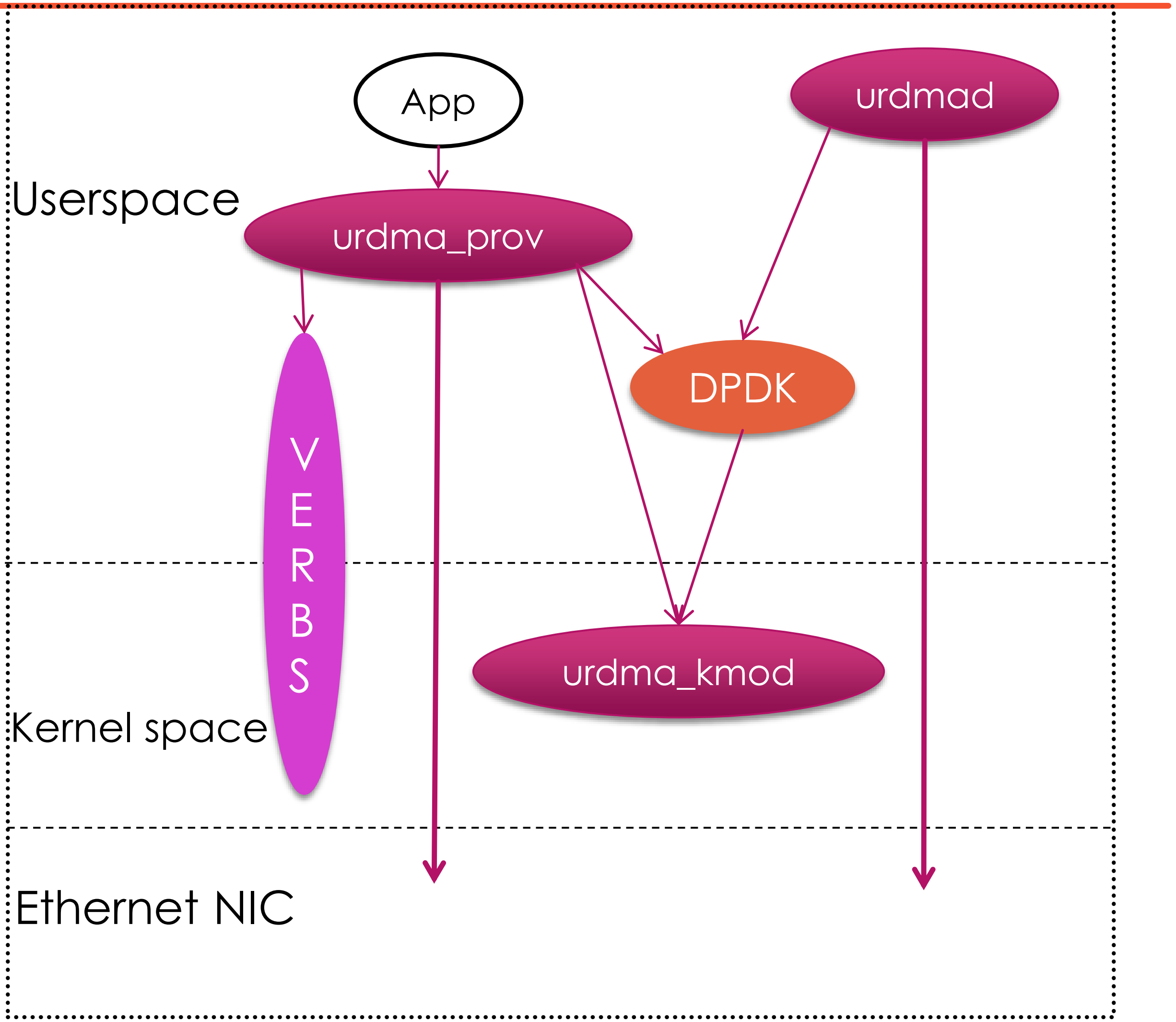
- Software emulation of RDMA using DPDK
- Goals
  - Low latency, high throughput
  - Run on commodity Ethernet NIC
  - Run unmodified verbs applications
  - Perform data transfers in userspace using DPDK
- Prior work: softiwarp/softroce
  - Perform data transfer in kernel space using kernel sockets
- Why urdma?
  - Ease of development, easy to use as a development vehicle for new RDMA features
  - Storage applications; integration with SPDK (Storage Performance Development Kit)

Implementation

urdma: Components

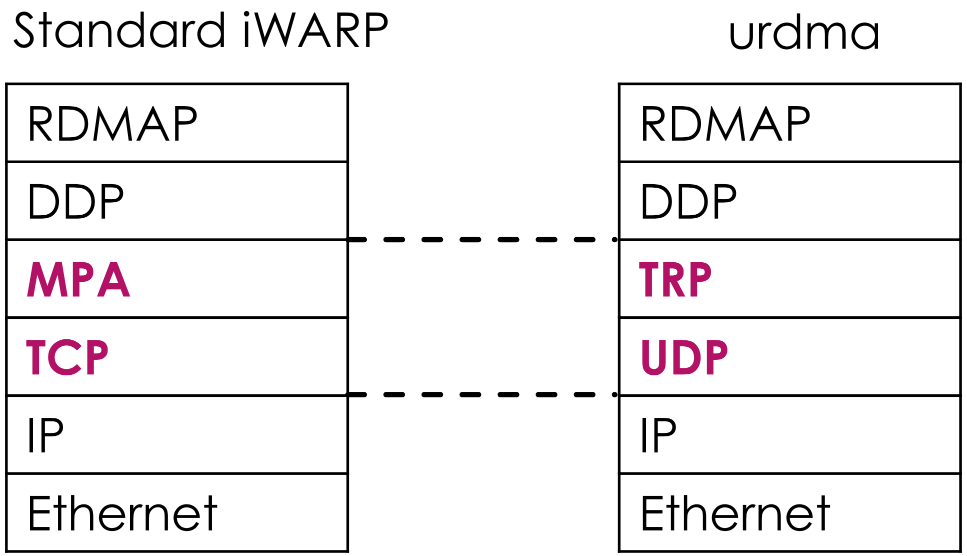
Multi-process application

- **urdma_kmod**: Loadable kernel module for RDMA CM support
- **urdmad**: DPDK primary process
- **urdma_prov**: User verbs provider library; applications run as DPDK secondary process



urdma: Protocol

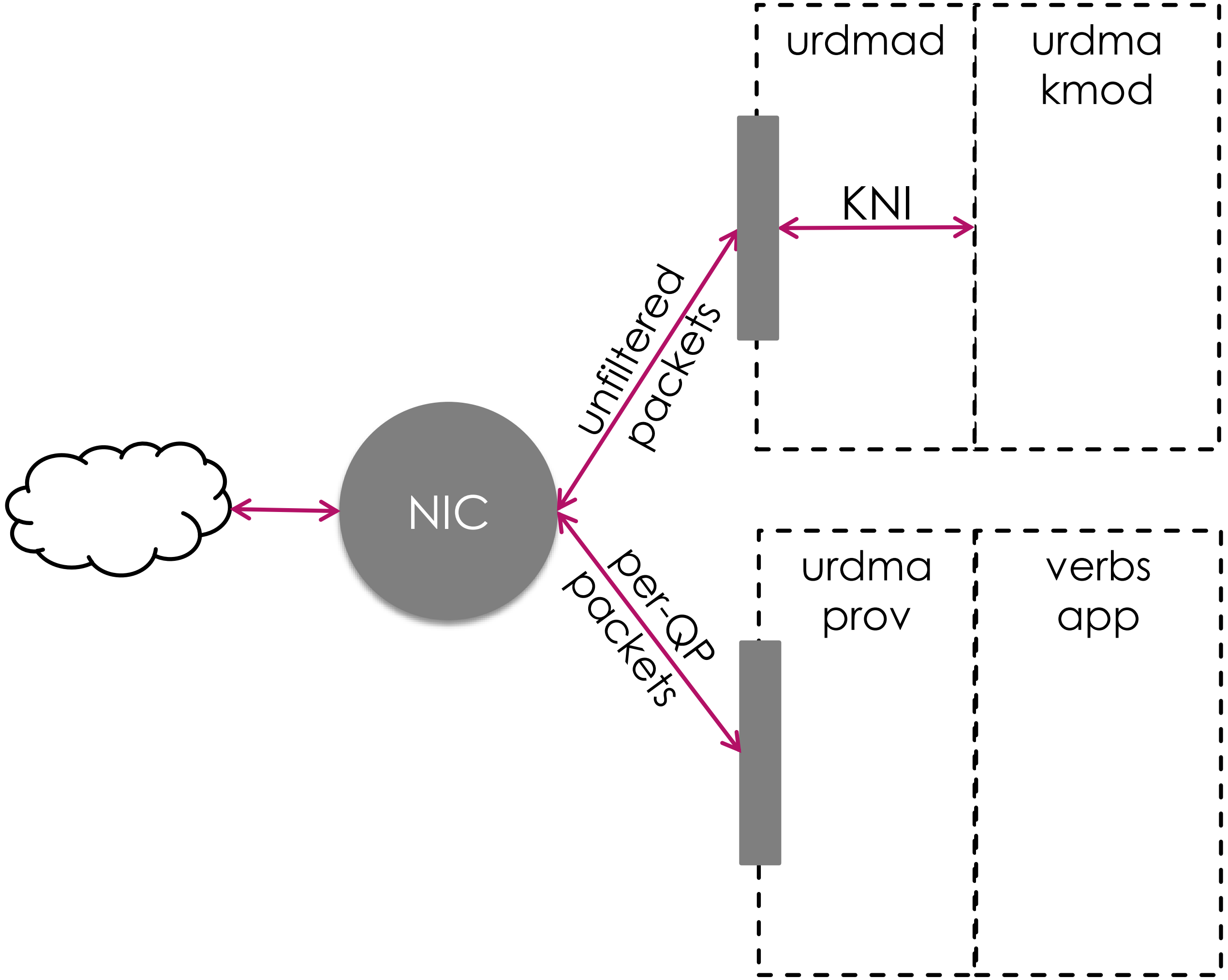
- Implements iWARP DDP and RDMAP protocols
- Runs over UDP transport protocol
  - TRP (Trivial Reliability Protocol) as thin reliability shim
  - Avoid byte-stream nature and state machine of TCP



Standard iWARP	urdma
RDMAP	RDMAP
DDP	DDP
MPA	**TRP**
TCP	**UDP**
IP	IP
Ethernet	Ethernet

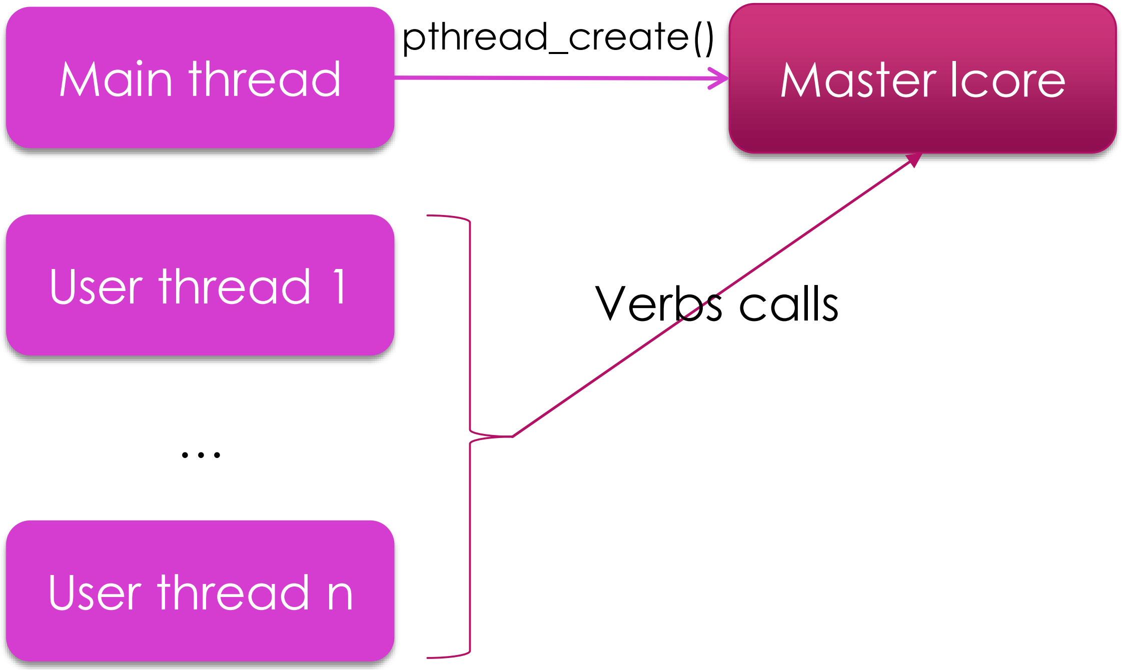
urdma: Packet Processing

- urdmad assigns each RDMA queue pair a hardware receive/transmit Ethernet queue
  - To allow verbs applications to access the NIC independently
- Ethernet NIC hardware filters used to separate packets into RX queues
  - Using **Flow Director** or **ntuple** filtering
  - urdmad forwards all unfiltered packets on each interface to kernel
  - For each established connection, packets filtered to specific receive queue—received directly by verbs application via urdma_prov



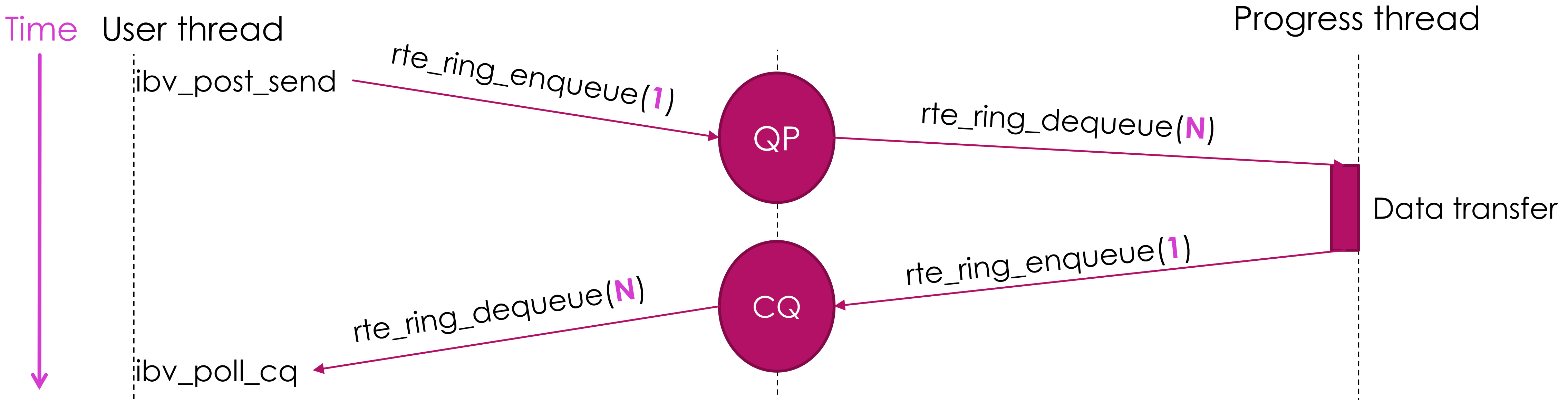
urdma initialization issues: rte_eal_init()

- As a verbs provider library, we want DPDK to be invisible to the user application
  - We call rte_eal_init() in our own implementation
- Our provider code is only run if urdma kernel module loaded and urdmad master process started
- Specific issues with rte_eal_init()
  - Takes command-line arguments
    - We construct our own fake argument list
  - Changes CPU affinity of calling thread
    - We create a new thread and call rte_eal_init() from that thread
    - Tell rte_eal_init() not to create other lcores
- All verbs applications must run as the same user (not necessarily root)

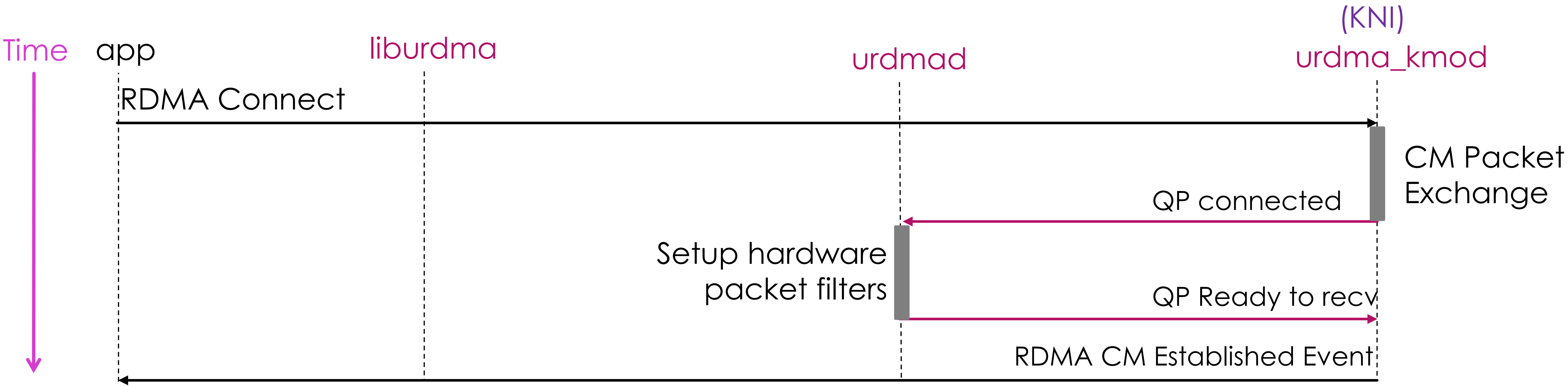


urdma_prov: Data Transfer

- Data transfer done in background progress thread
  - Separates DPDK operations from application threads
  - Allows progress for RDMA READ and RDMA WRITE outside of verbs calls
  - Inter-thread communication done via ring queues
    - ➢ Enqueue one entry at a time
    - ➢ Dequeue entries in bulk



urdma_kmod: Connection Establishment



urdmad must enable receive filter before first packet arrives

Evaluation

Performance Test Setup

2 pairs of systems with Ubuntu 16.10 with Linux 4.8.0-46-generic kernel, DPDK 16.07.2, PCIe generation 3

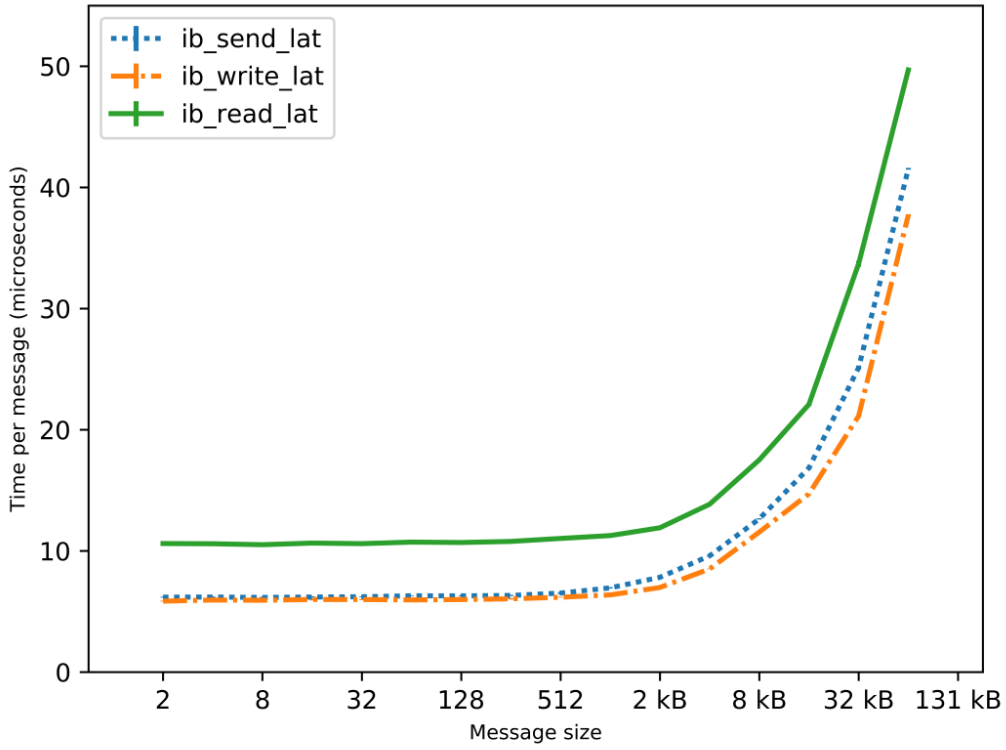
- urdma/softiwarp (Software Implementations)
  - Dual Intel Xeon ES-2630 v4 CPUs @ 2.20GHz
  - 64 GB DDR4 RAM
  - **Intel XL710 40GbE** NIC (firmware v5.05)
- Reference iWARP Hardware Implementation
  - Dual Intel Xeon E5 2609 CPUs
  - 64 GB DDR3 RAM
  - **Chelsio T580-LP-CR** Unified Wire Ethernet controller (firmware v0.271.9472)
- Applications used
  - perftest version 3.0+0.18.gb464d59-1

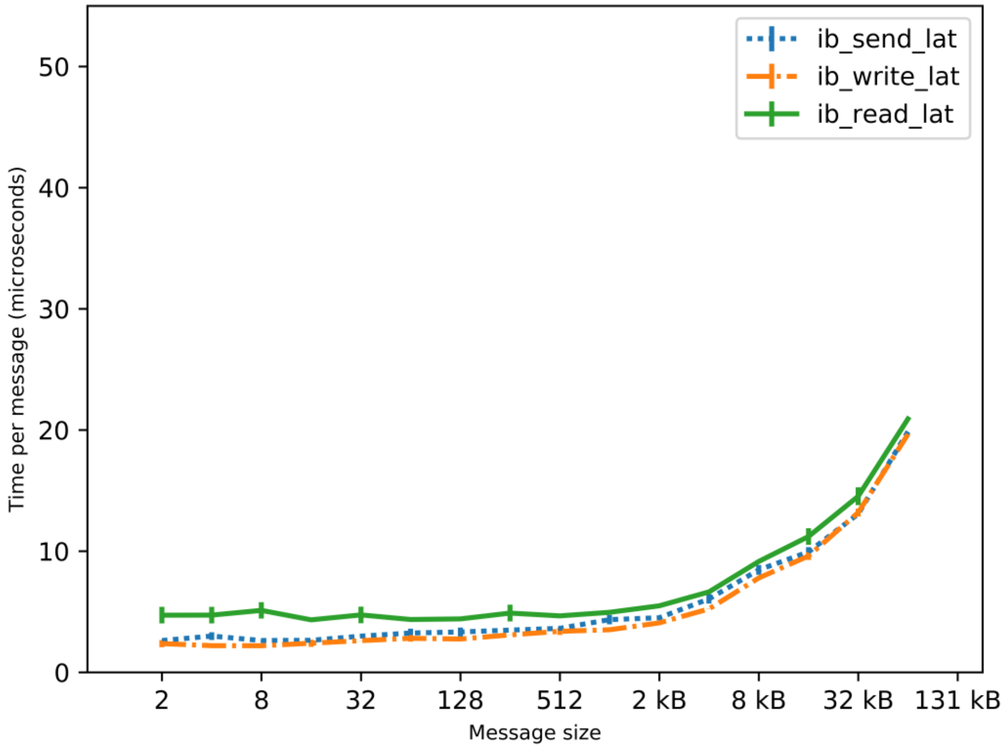
Perftest Latency: urdma vs. Chelsio iWARP NIC

urdma (Software)

Hardware

Worse

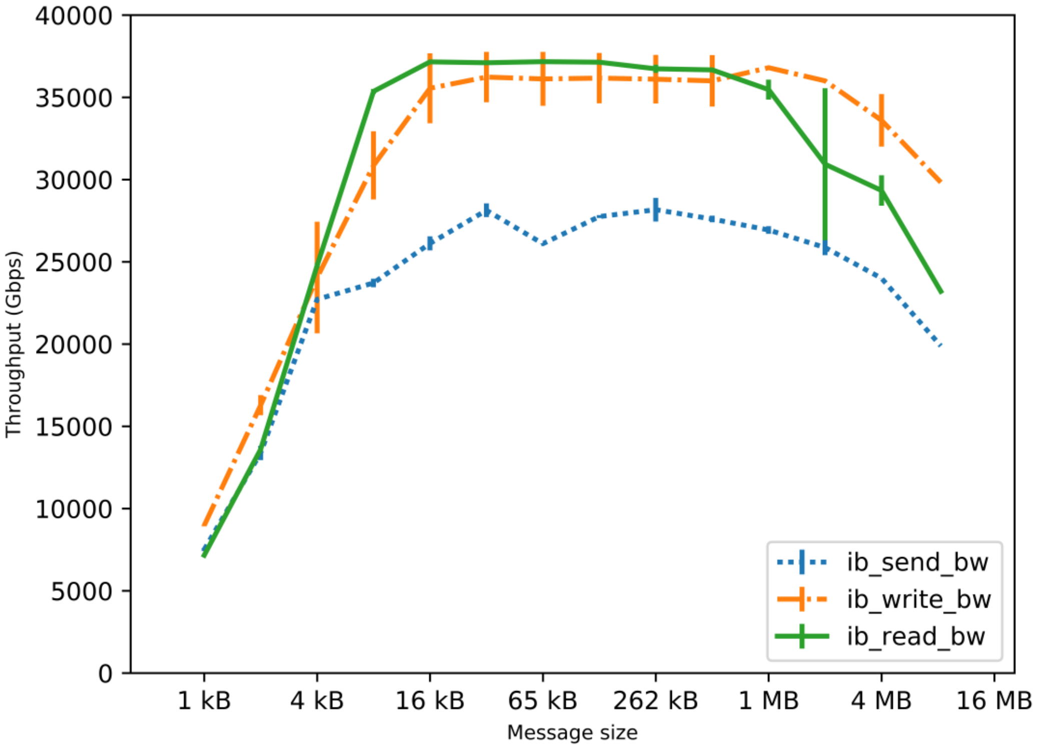




Better

Perftest Throughput: urdma vs. Chelsio iWARP NIC

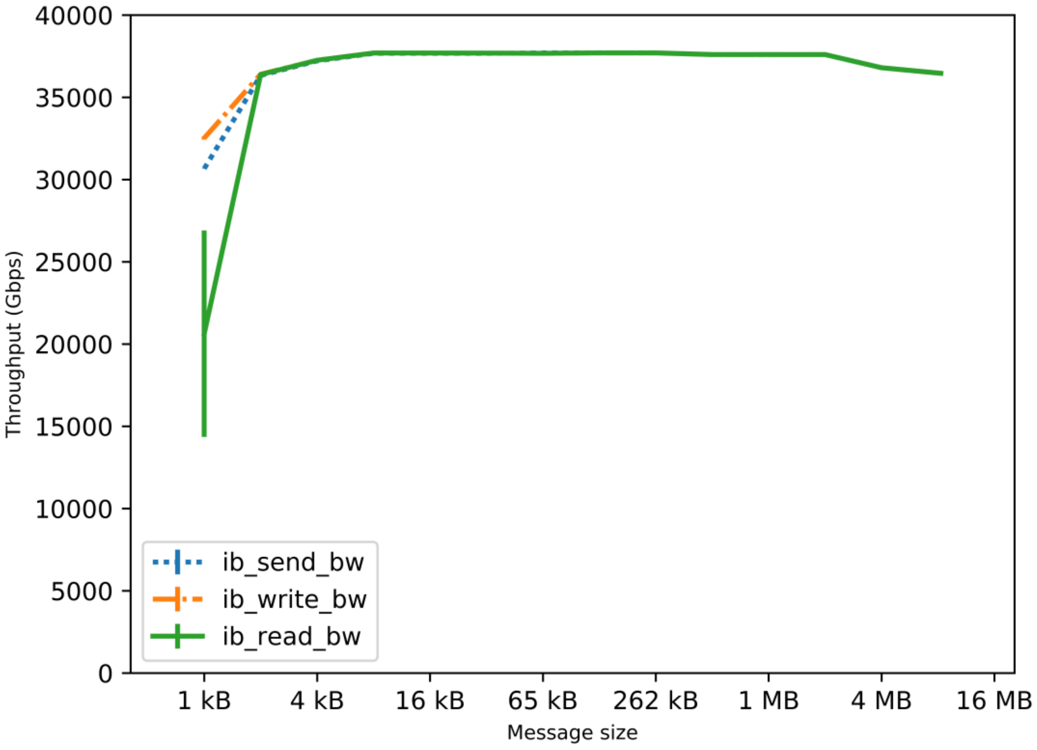
urdma (Software)



Better

Worse

Hardware



Summary

Summary

- urdma
  - Software emulation of RDMA
  - Runs unmodified RDMA verbs applications
  - Performs all data transfer in userspace
  - No dependency on specific hardware
  - Achieves reasonable performance
- Future work
  - Zero copy sends?
  - Using urdma for NVMf traffic
  - Integration with emerging storage class memory technologies

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Thanks!

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Questions?

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urdma download: https://github.com/zrlio/urdma