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13th ANNUAL WORKSHOP 2017

URDMA: RDMA VERBS OVER DPDK

Patrick MacArthur, Ph.D. Candidate

University of New Hampshire

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BACKGROUND

EXISTING SOFTWARE RDMA DRIVERS

- **softiwarp and rxe**
  - Implement iWARP over TCP and RoCEv2, respectively
  - Data transfer in kernel space
  - Run unmodified verbs applications
  - Designed with performance in mind
- **libfabric sockets provider**
  - Implements private protocol
  - Userspace implementation using TCP/IP sockets
  - Cannot run verbs applications
  - High performance explicitly not a goal

SOFTWARE VERBS DRIVERS: KERNEL VS. USER SPACE

Why not implement a verbs driver using sockets API from userspace?

- **Userspace verbs API design choices**
  - Verbs will not load a userspace driver without a corresponding uverbs device exposed by the kernel
  - Connection management deferred to kernel by librdmacm
  - CQ events delivered from kernel
- **Using userspace sockets API requires both userspace and kernel involvement**
- **Using kernel sockets API**
  - Incoming RDMA READ and RDMA WRITE can be handled entirely in kernel without waking user thread
  - Can use tricks like sendpage() to send TCP segments with zero-copy
- **Path of least resistance has been implementation using sockets API in kernel**

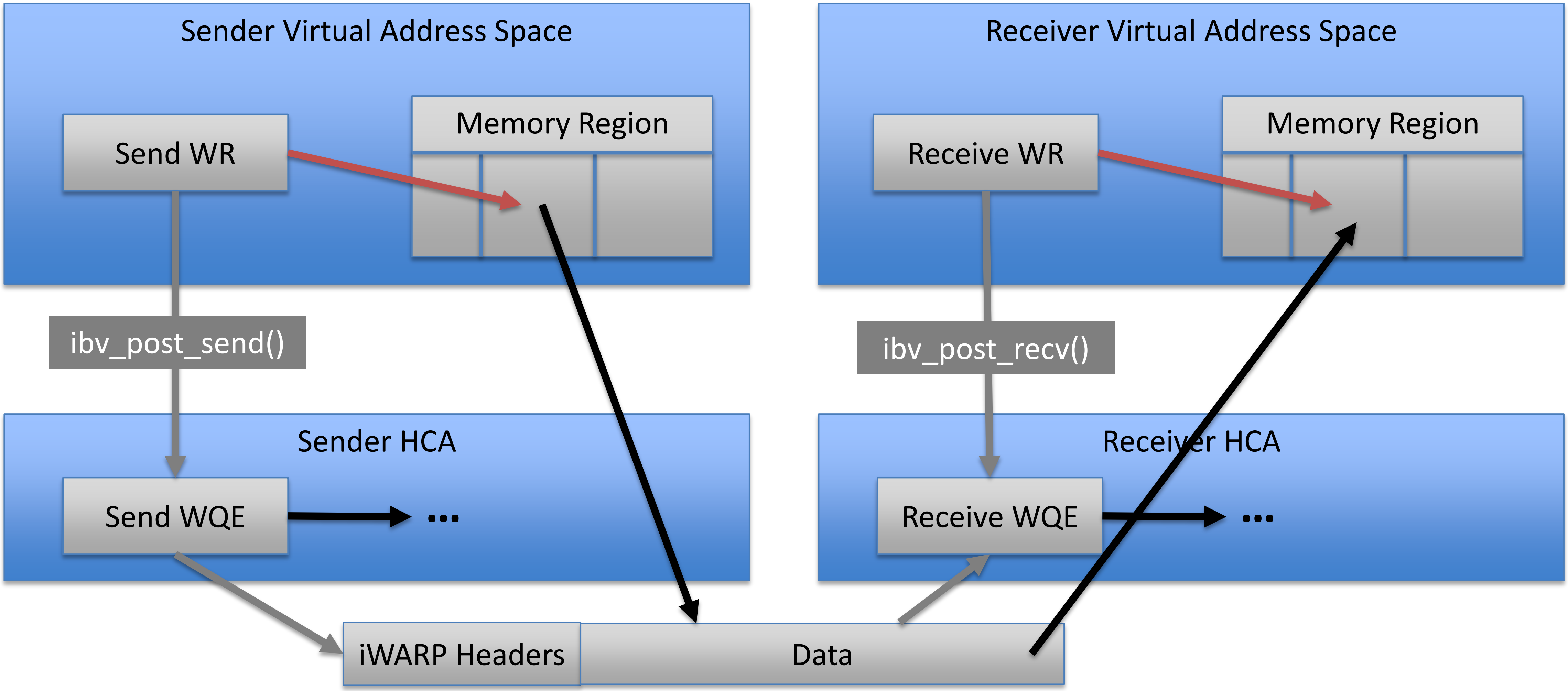
URDMA: USERSPACE RDMA

- **Goals**
  - Prototype software RDMA driver with data transfer entirely in userspace
  - Run unmodified verbs applications
  - High performance
- **Why a userspace implementation?**
  - Ease of development, makes it easy to use as a development vehicle for new RDMA features
  - Avoid context switches between kernel and userspace (especially for small SENDs)
- **Implementation uses DPDK (Data Plane Development Kit)**

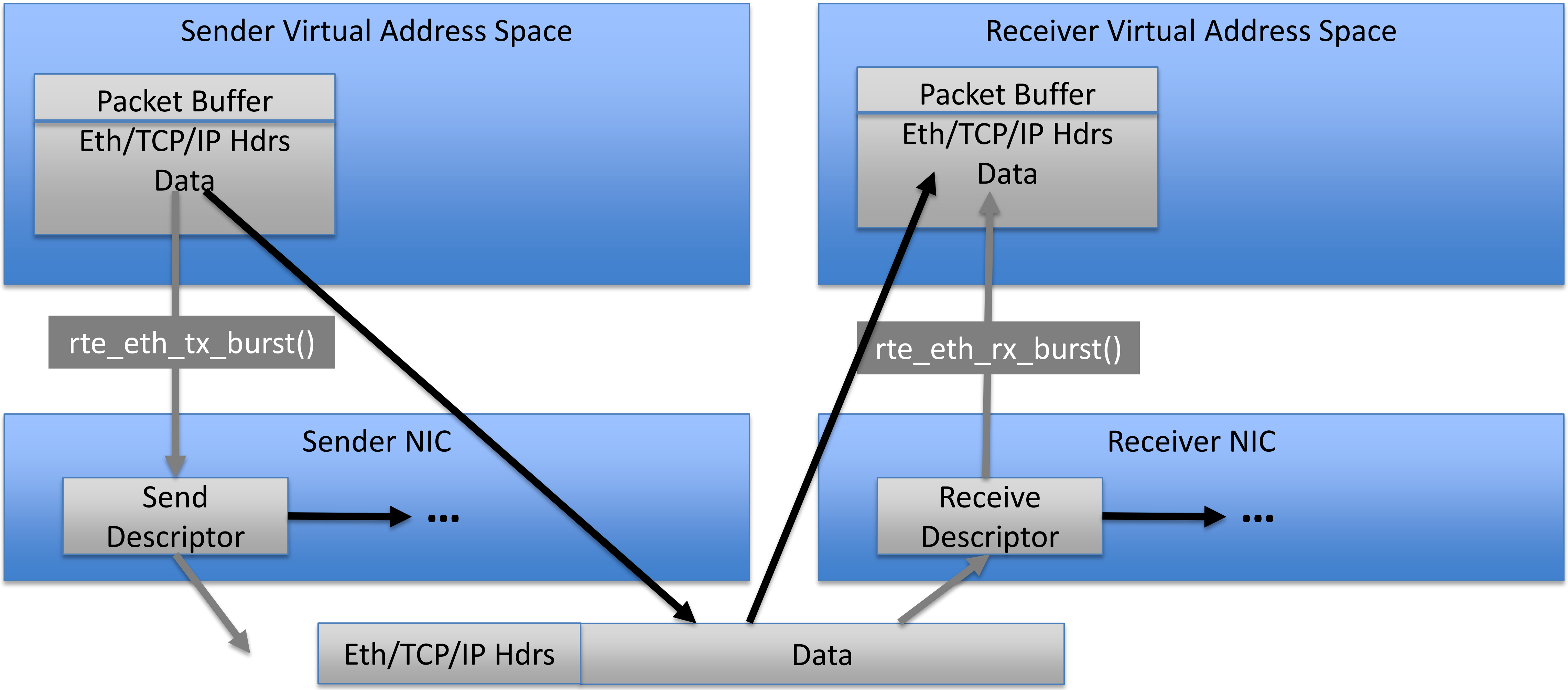
BACKGROUND: DPDK (DATA PLANE DEVELOPMENT KIT)

- **DPDK leverages Linux UIO/VFIO to map Ethernet NICs into userspace**
- **Features:**
  - Bulk packet transmit/receive to/from hardware NIC queues
  - NUMA-aware memory buffer pool allocation using hugepages
  - High performance multi-core data structures
  - Hardware packet filtering
  - TCP/UDP offloads, including checksum calculation
- **Does not provide:**
  - RDMA functionality
  - Network-layer or transport-layer protocol logic
- **Using DPDK for userspace RDMA verbs eliminates kernel from data transfer path**

RDMA SEND/RECV MESSAGE TRANSFER



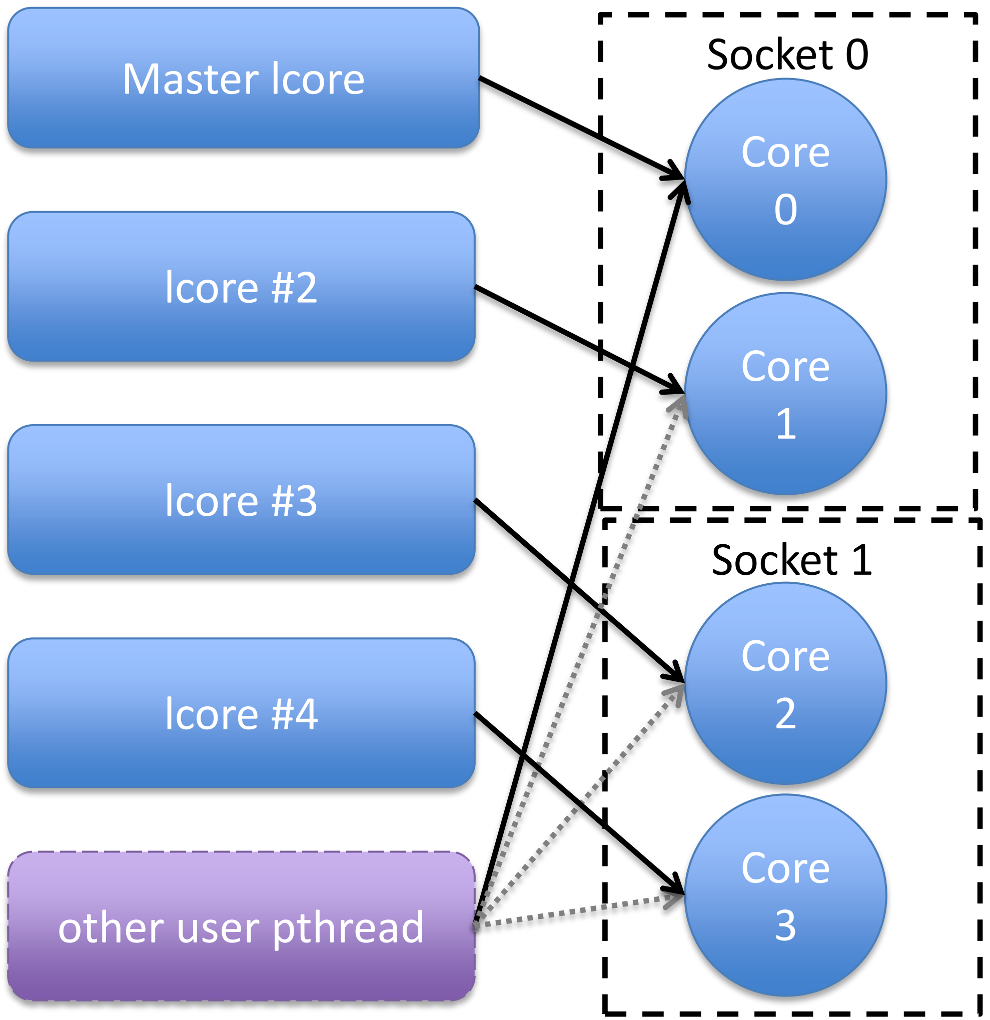
DPDK PACKET TRANSFER



BACKGROUND: DPDK THREAD MODEL

DPDK process consists of threads called "logical cores" or "lcores"

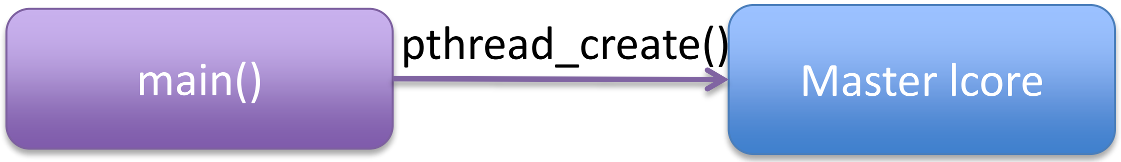
- DPDK creates 1 "lcore" thread per CPU core by default
- Thread which initializes DPDK is "master" lcore
- CPU affinity of each thread, including master, is set to run on a specific CPU core
- API allows launching tasks on other logical cores
- DPDK API expected to be called from lcores, in particular ring queues and memory pools rely on this
- We tell DPDK *not* to create lcores other than the master lcore



BACKGROUND: DPDK THREADS AND LIBRARIES

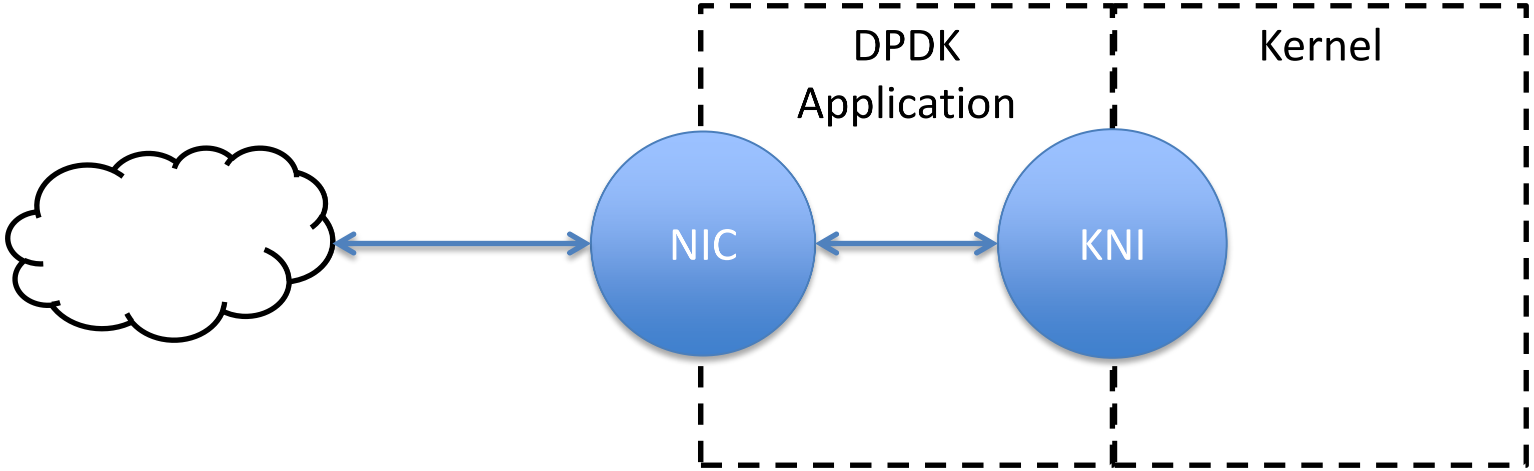
DPDK is more of an application framework than a library

- **DPDK initialization function**
  - Takes command-line arguments
  - Consumes all available hugepages by default
  - Changes CPU affinity of calling thread
- **To use DPDK from library, we create a thread and call DPDK initialization from there**
  - Pass parameter to not create further lcores
  - Separate DPDK thread from user threads
  - We do not affect CPU affinity of user threads



BACKGROUND: DPDK KNI

- **KNI (Kernel Network Interface)**
  - Creates a virtual network interface in the kernel
  - Loosely associated with a DPDK Ethernet hardware NIC
  - Can exchange packets between kernel and userspace
  - Useful for small interactions between kernel service and DPDK application



URDMA: DESIGN AND IMPLEMENTATION

URDMA: DESIGN

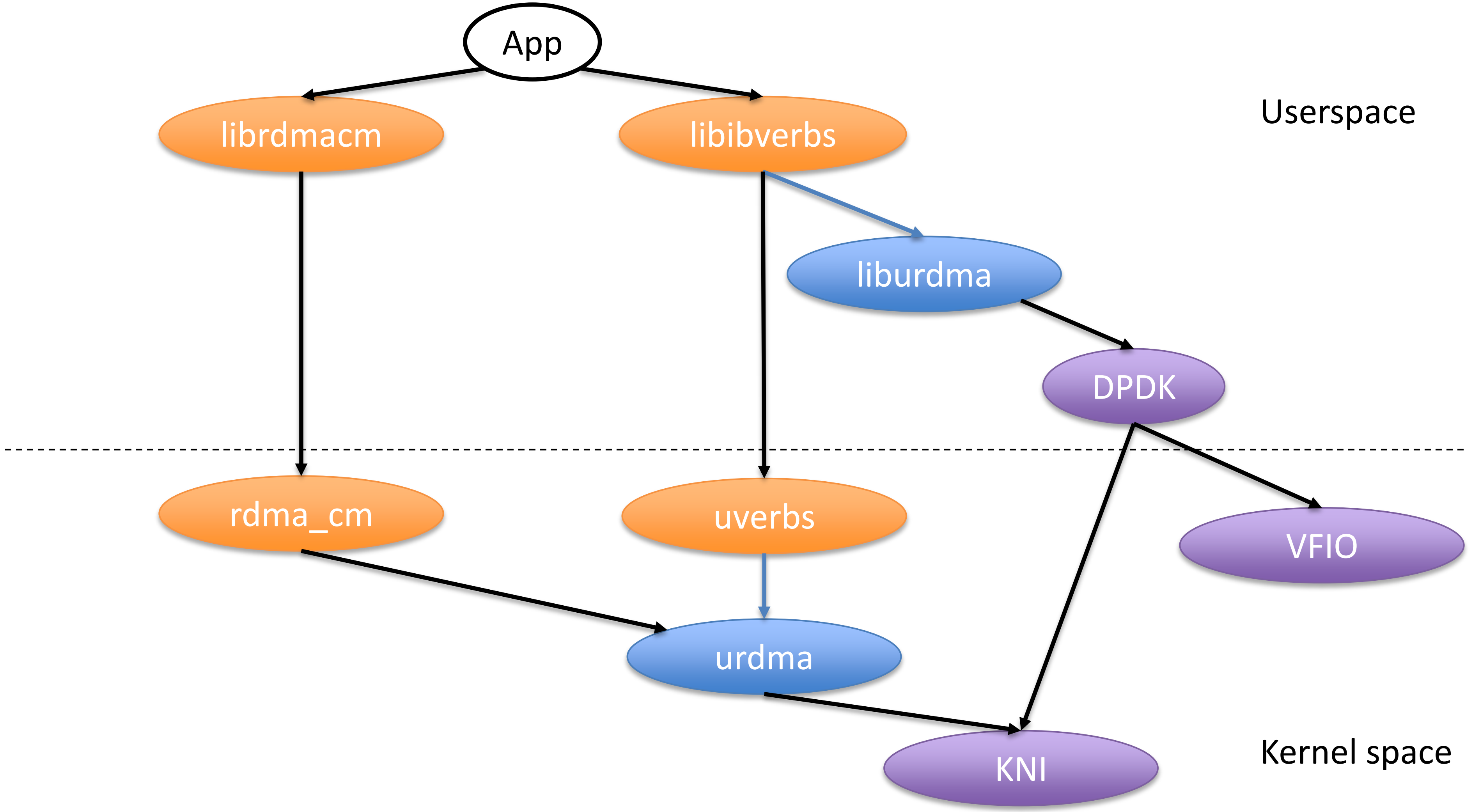
- **Implements iWARP DDP and RDMAP protocols**
- **Runs over UDP transport protocol**
  - TRP (Trivial Reliability Protocol) provides a thin shim for reliability
  - Simplifies implementation considerably
- **Small kernel component**
  - Required for libibverbs initialization, RDMA CM, and CQ events
  - Performs connection establishment before ceding control of UDP “connection” to liburdma
  - Uses KNI to send/receive packets to/from userspace
- **Packet processing done in background thread**
  - Ensure quick response to RDMA packets and KNI events
- **Hardware receive filter used to assign queue pairs to NIC receive queues**

URDMA: MULTI-PROCESS SUPPORT

- **DPDK maps Ethernet NIC hardware into userspace → owned by that process**
  - Can delegate to secondary processes that explicitly cooperate
  - DPDK considers primary + secondary processes as one combined application
  - DPDK threads in combined application cannot share the same lcore identifier
- **In urdma, primary process is a user daemon urdmad**
  - Initializes DPDK
  - Registers secondary processes with separate core mask
  - Assigns Ethernet NIC hardware RX/TX queues to urdma processes
  - Sets up Ethernet NIC hardware filtering rules
- **liburdma verbs provider**
  - Sets up process as secondary DPDK process
  - DPDK “master” lcore acts as background progress thread
- **Each liburdma process has direct access to its Ethernet NIC hardware queues**

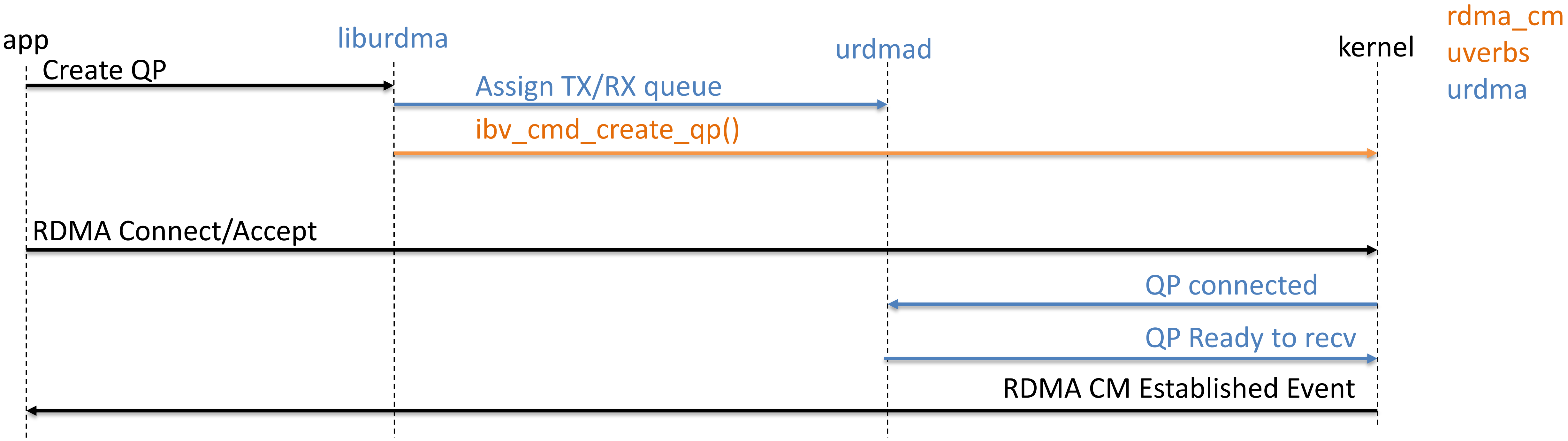
URDMA: COMPONENTS

Legend:
urdma
Verbs-related
DPDK-related

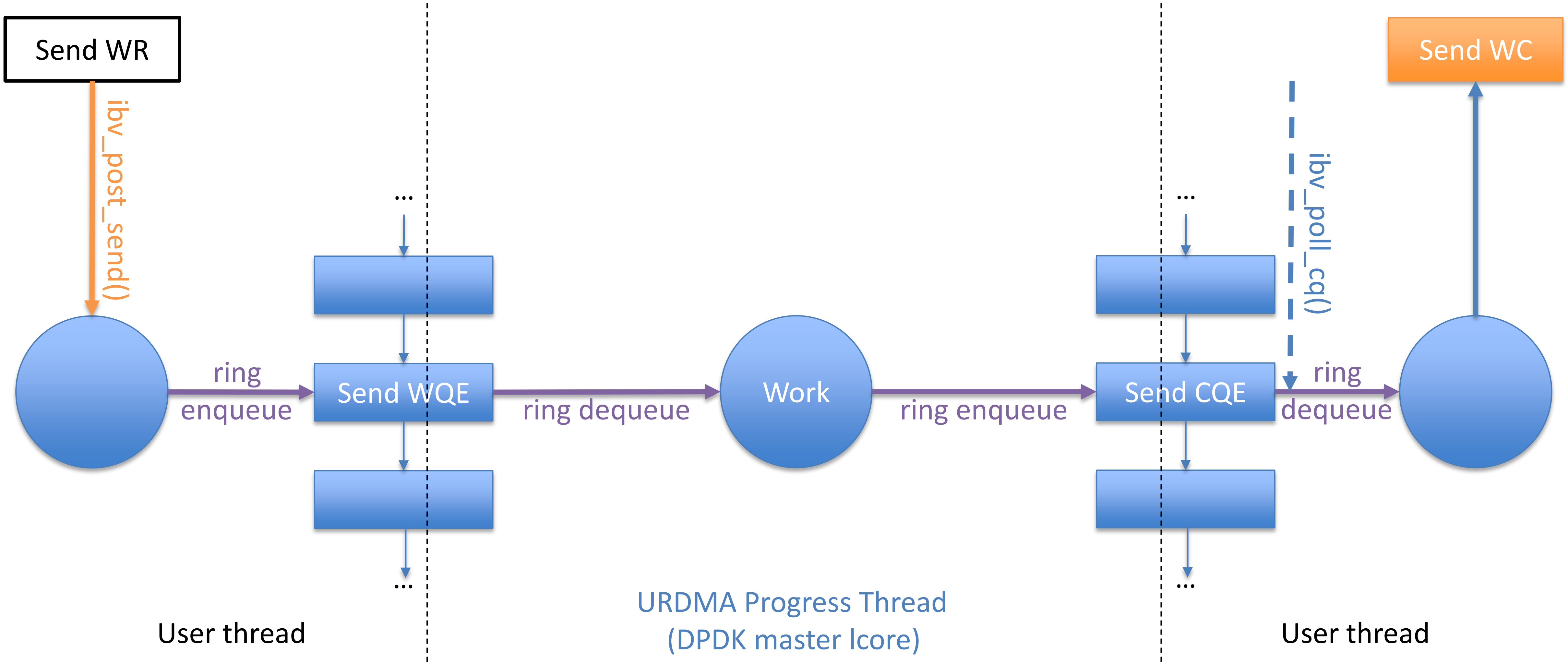


URDMA CONNECTION ESTABLISHMENT

- **Connection establishment done in kernel space**
- **In userspace:**
  - Each queue pair must be assigned a Ethernet NIC hardware send and receive queue
  - Hardware receive filtering rules must be assigned before first packet arrives
  - Private character device used to communicate connection establishment



URDMA DATA TRANSFER

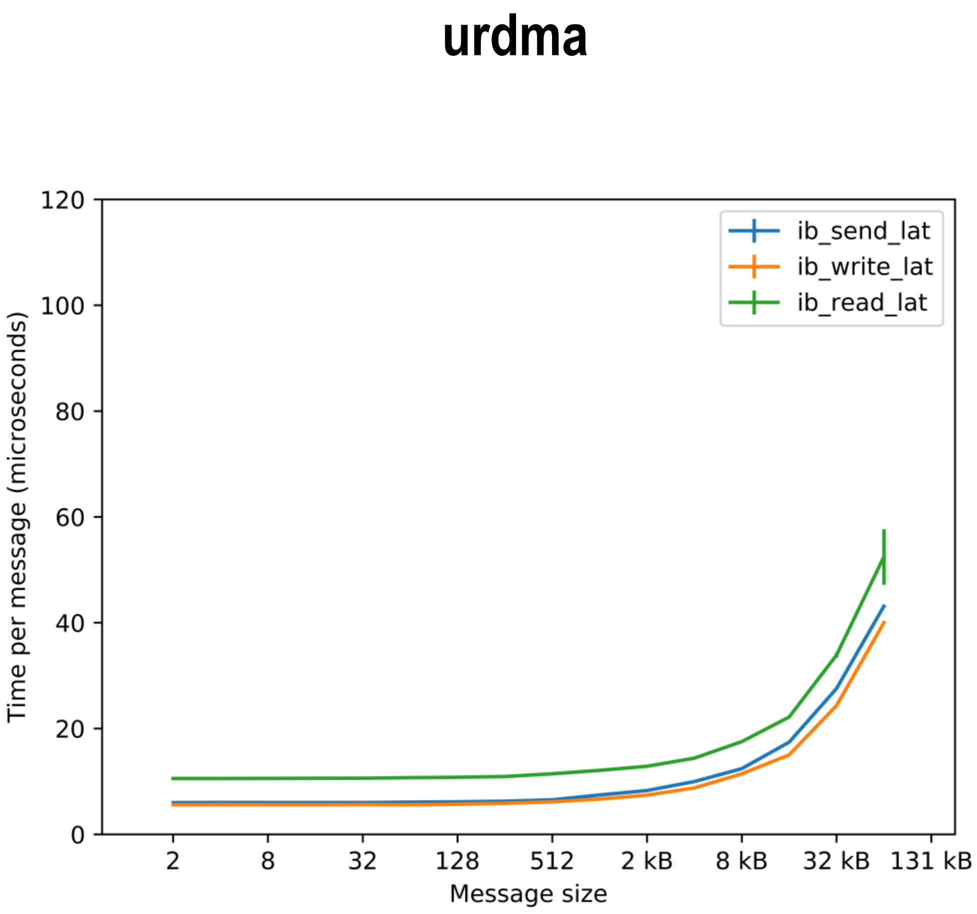


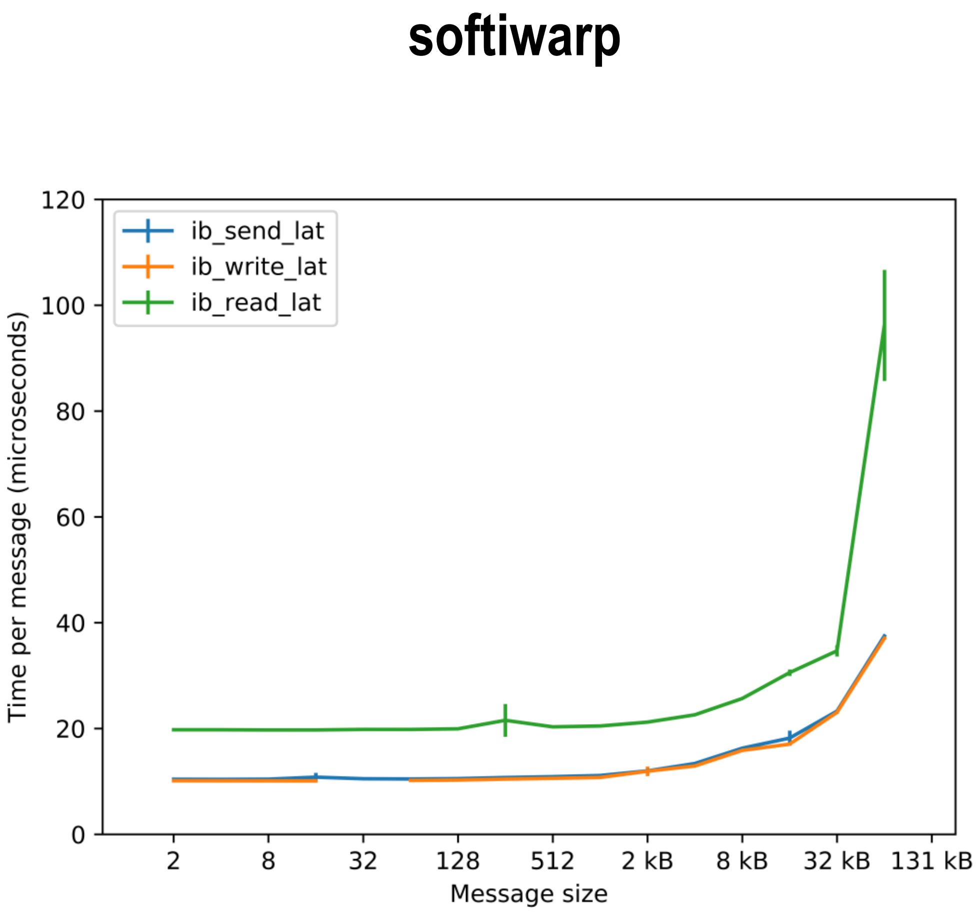
PERFORMANCE

PERFORMANCE: OVERVIEW

- **Two identical systems:**
  - Supermicro SYS-6028R-T
  - 2 Intel Xeon ES-2630 v4 CPU @ 2.20GHz
  - 64 GB DDR4 RAM
  - PCIe generation 3
  - Ubuntu 16.10 with inbox 4.8 kernel
  - Intel XL710 40GbE NIC
  - Verbs and RDMA CM as supplied with Ubuntu 16.10
- **Applications used**
  - perftest version 3.0+0.18.gb464d59-1
  - UNH EXS (Extended Sockets) 1.4.1 (https://www.iol.unh.edu/expertise/unh-exs)

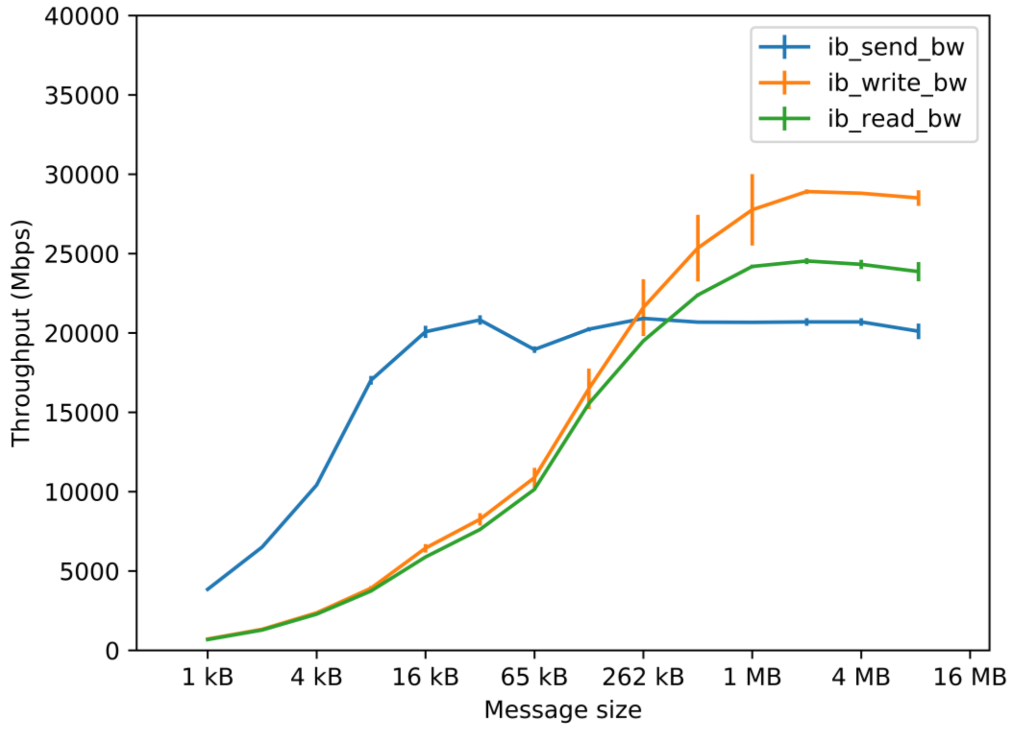
RAW VERBS: LATENCY



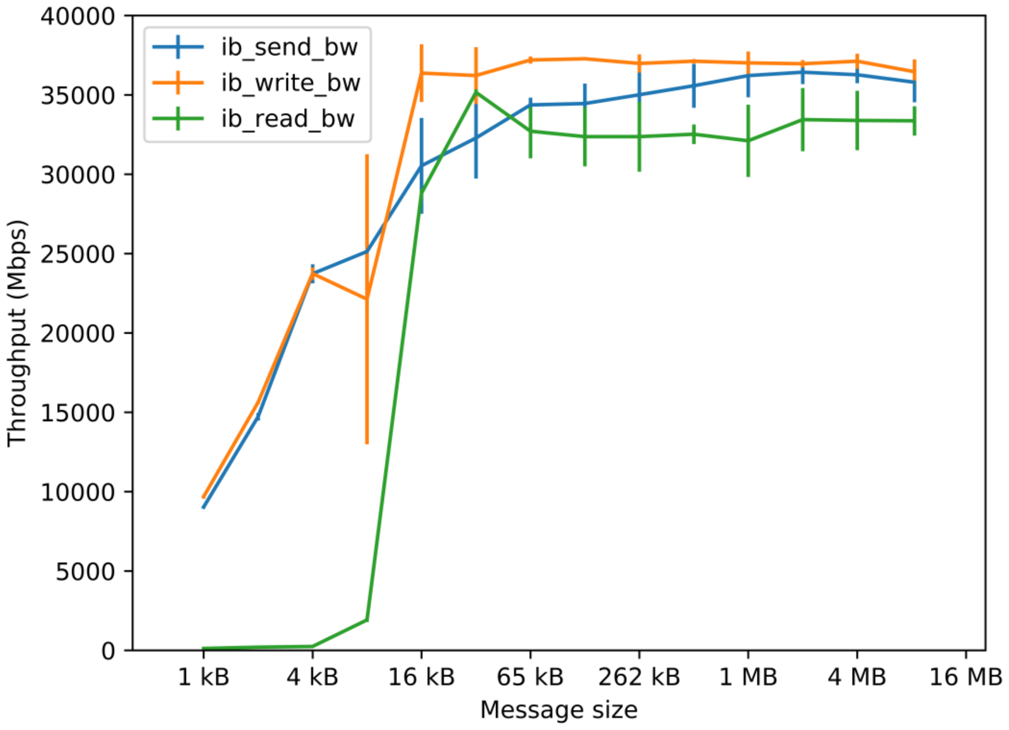


RAW VERBS: THROUGHPUT

urdma

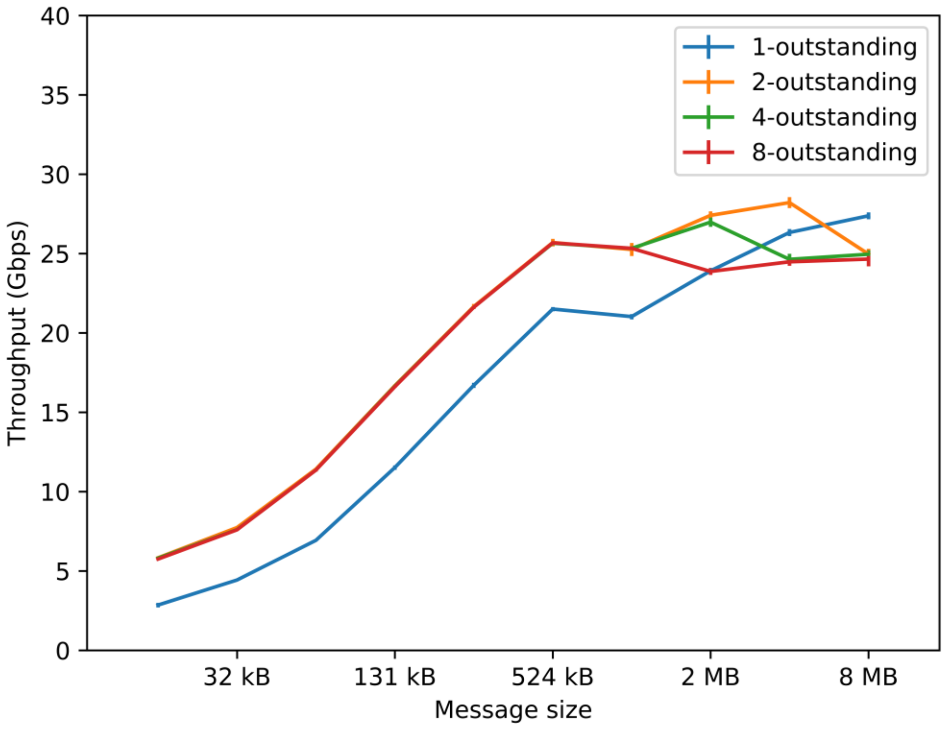


softiwarp

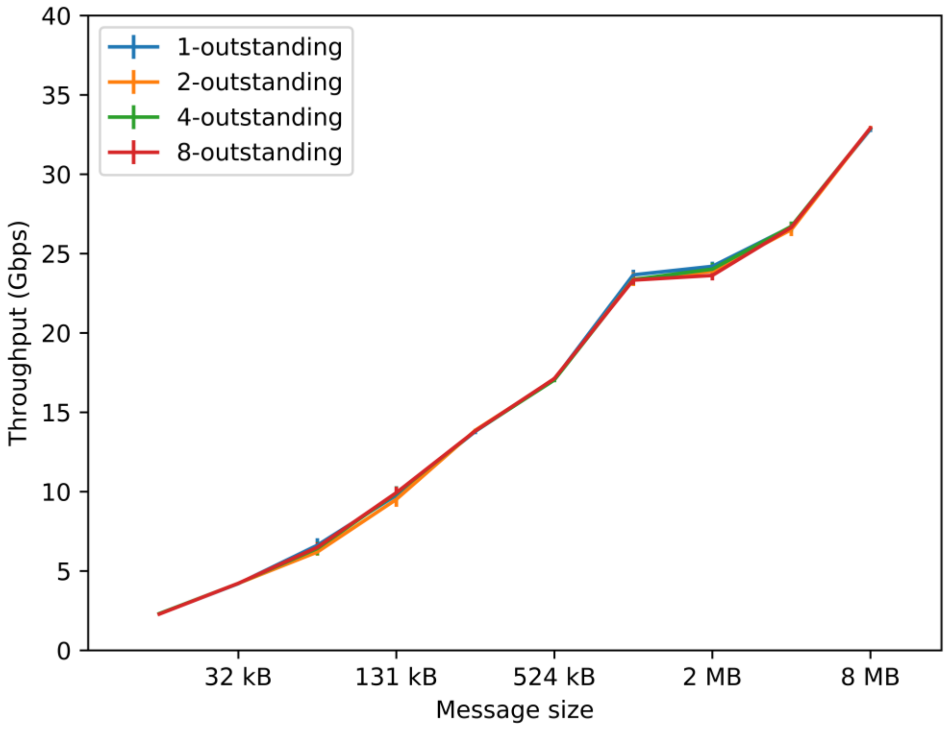


UNH EXS: THROUGHPUT

urdma



softiwarp



CONCLUSION

URDMA SUMMARY

- **Existing software RDMA implementations done in kernel space**
- **DPDK allows us to implement RDMA verbs data transfer in userspace**
  - Eliminates all kernel involvement in data transfer path
  - Small kernel module for connection management
- **Runs unmodified verbs applications**
- **Designed with performance in mind**
  - Good small message latency
  - Needs tuning for throughput
- **Future work**
  - Investigate zero-copy transmit support
  - libfabric provider implementation
  - Reliable datagram support

URDMA DOWNLOAD AND STATUS

- urdma development done on GitHub
  - https://github.com/zrlio/urdma
- No formal release as of yet
- Not integrated into rdma-core
- Tested on Ubuntu 16.10 and DPDK 16.07

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THANK YOU

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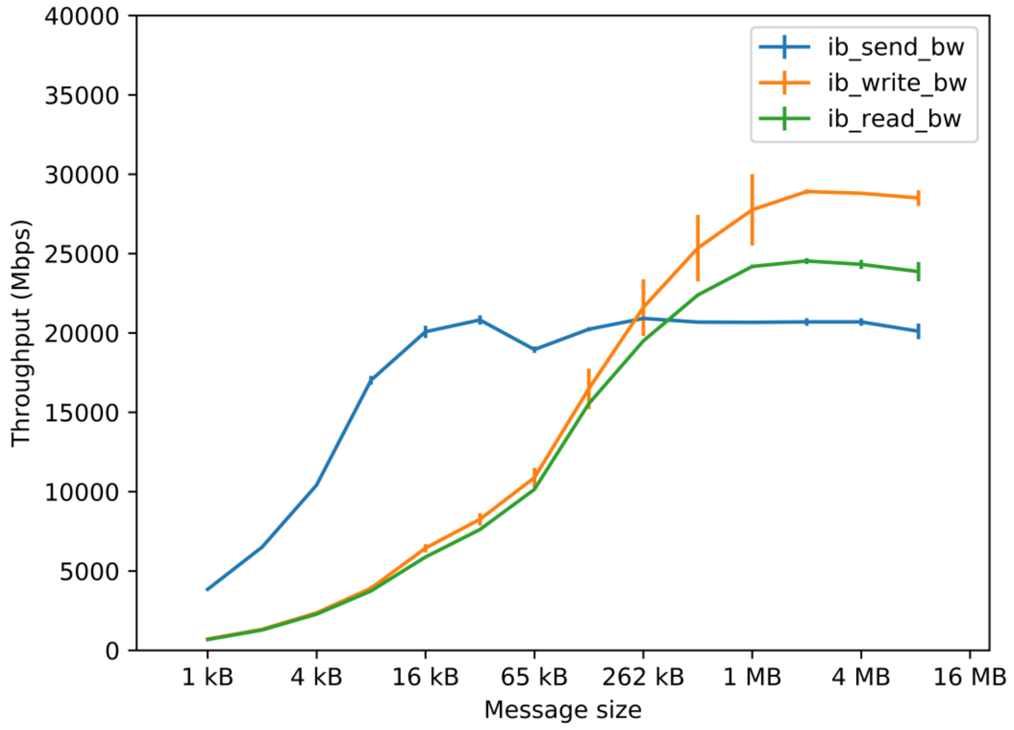
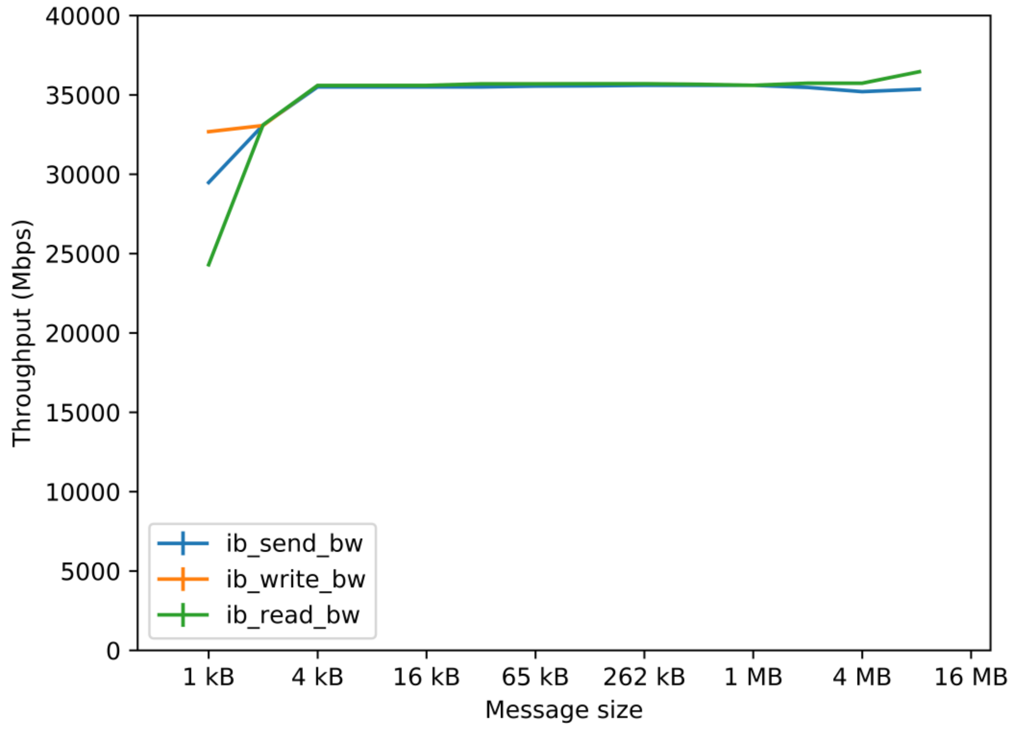
BACKUP

RAW VERBS: THROUGHPUT VS. HARDWARE RNIC

urdma on Intel XL710

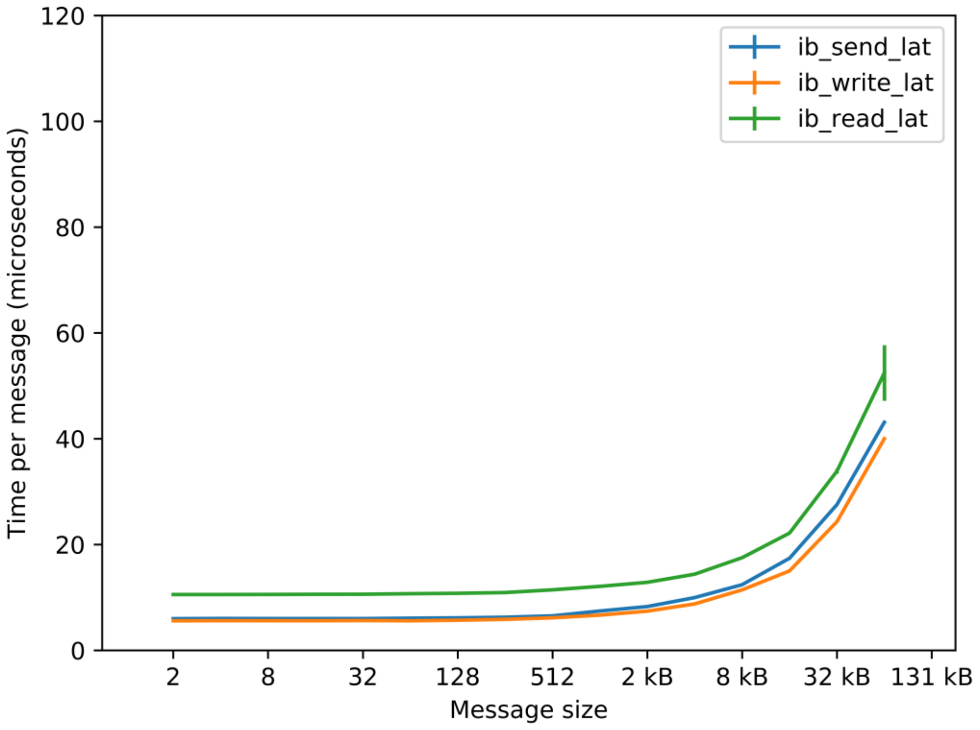


Chelsio T580-LP-CR iWARP



RAW VERBS: LATENCY VS. HARDWARE RNIC

urdma on Intel XL710



Chelsio T580-LP-CR iWARP