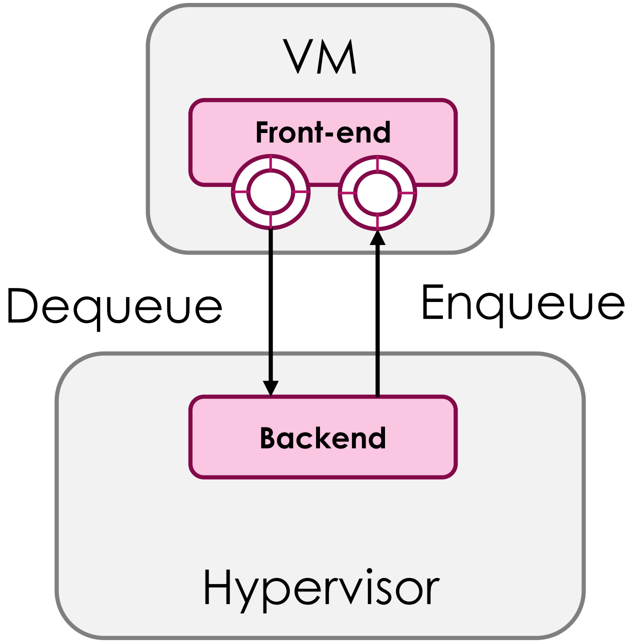
DPDK
DATA PLANE DEVELOPMENT KIT

Accelerating Para-Virtual I/O with CBDMA

JIAYU HU, INTEL

Para-Virtual I/O

- Para-virtual I/O is a virtualization technique to enhance VM I/O performance.
- VirtIO is a standard of para-virtual I/O, which consists of VirtIO front-end in VM and backend in hypervisor.
- Backend exchanges data with front-end via **copying packet buffers** between host and VM memory.



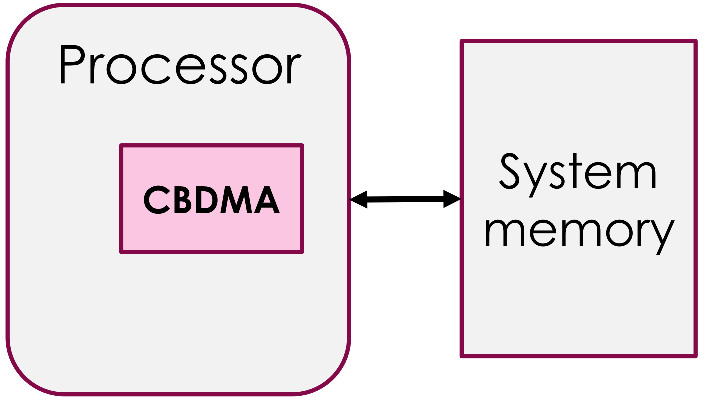
*The overhead of **copying large bulk of data** makes the **backend** become the **I/O bottleneck**.*

Crystal Beach DMA

- Crystal Beach DMA (CBDMA) is **a DMA engine** in the processor, which is extremely efficient in performing **memory copy operations**.
- No CPU intervention during data transfer.

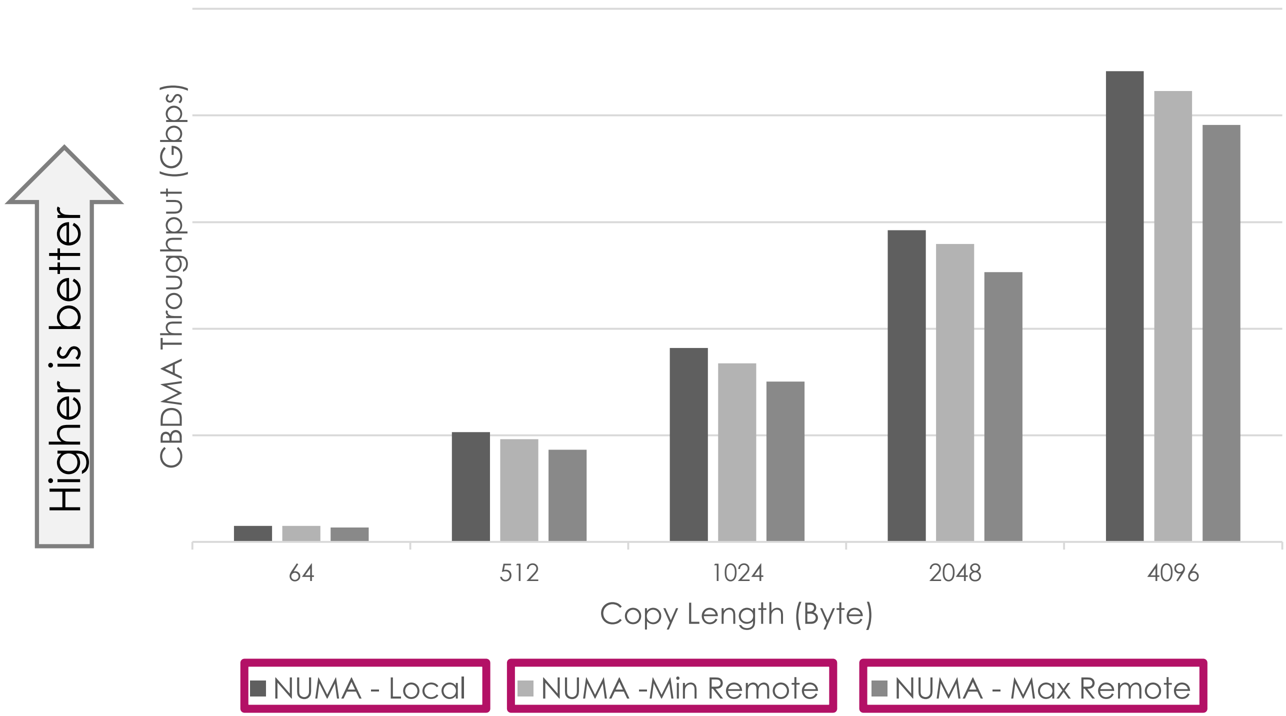
***Challenges of using CBDMA** to accelerate the backend:*

- *NUMA*
- *Copy buffer length*
- *CPU-CBDMA cooperation pipeline*



NUMA

- Influence from CBDMA and memory NUMA nodes



NUMA – Local:
CBDMA and Memory in same node.

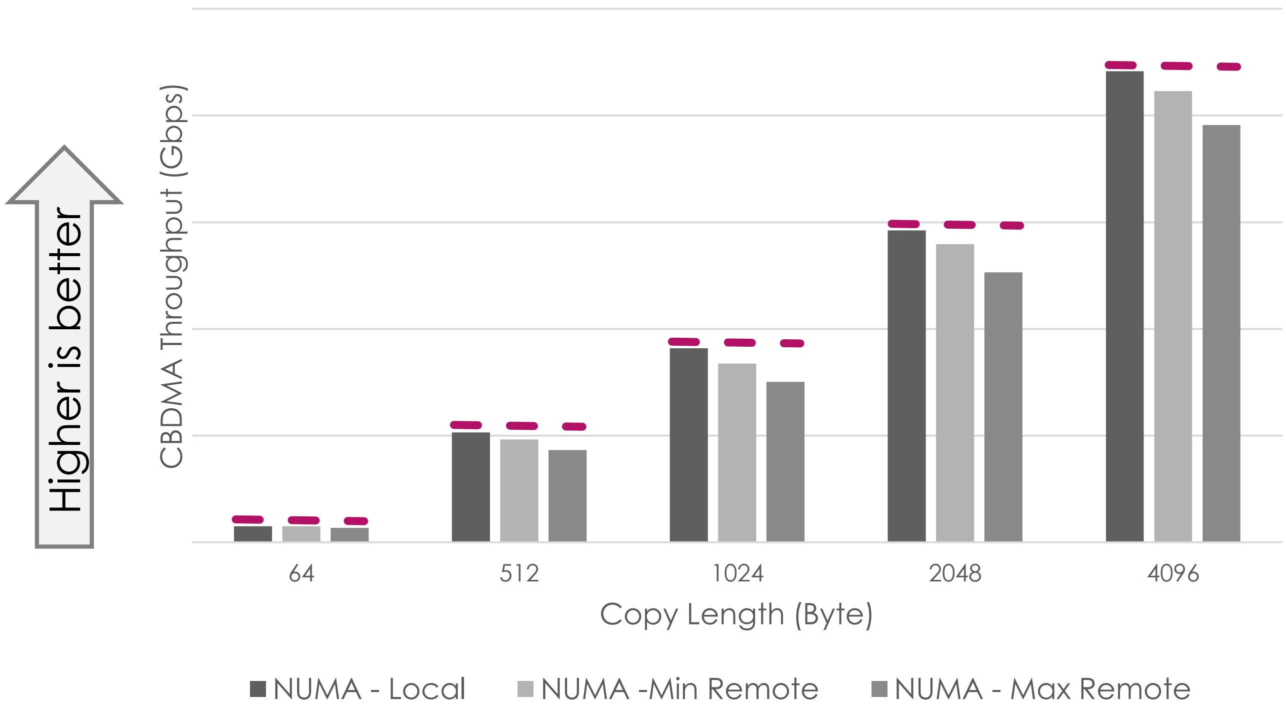
NUMA – Min Remote:
CBDMA and SRC Memory in same node, DST memory in another node.

NUMA – Max Remote:
CBDMA and Memory in different nodes.

CPU and CBDMA in the same NUMA node.

NUMA

- Influence from CBDMA and memory NUMA nodes

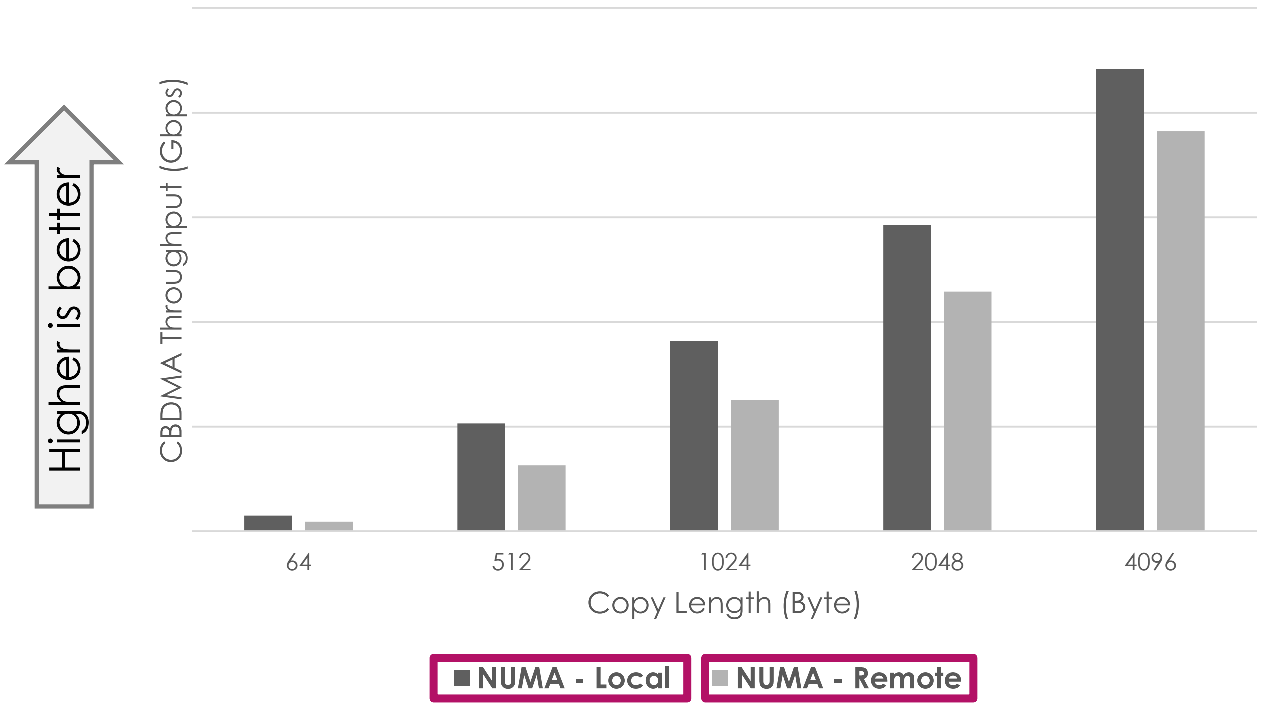


- CBDMA and memory in **same** NUMA node **improves** throughput **4% ~ 13%.**

CPU and CBDMA in the same NUMA node.

NUMA

- Influence from CBDMA and CPU NUMA nodes



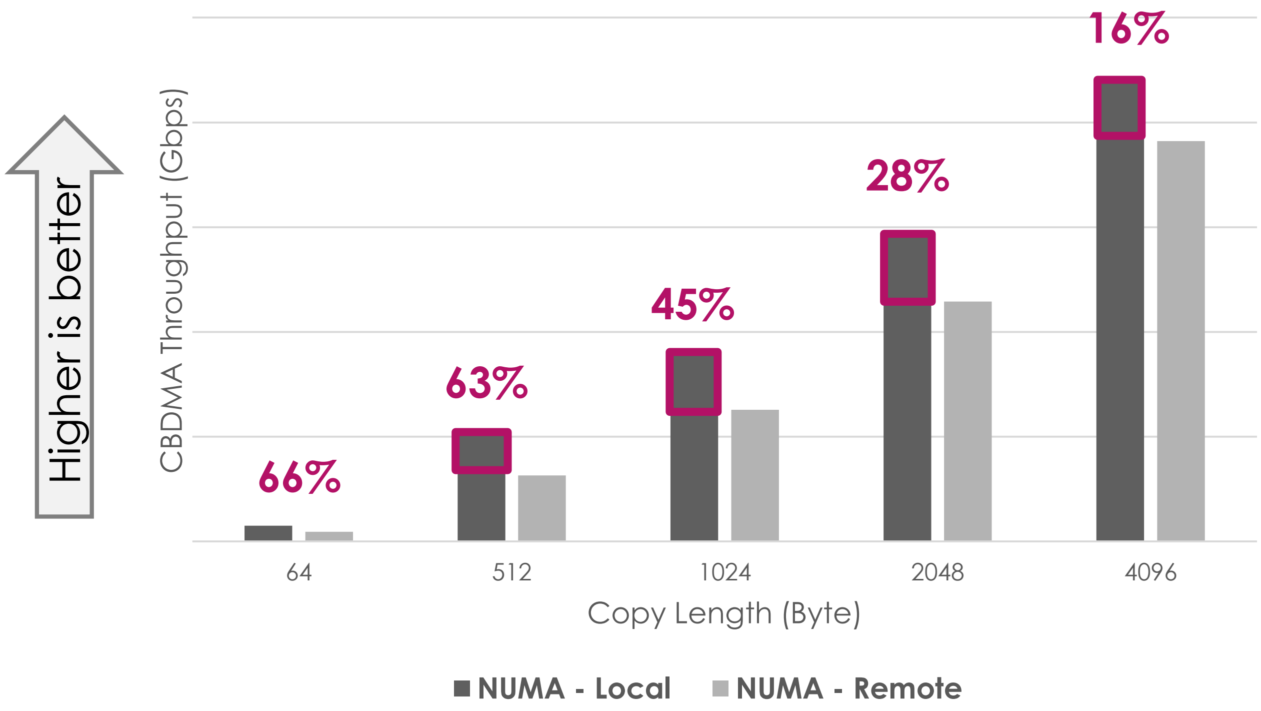
NUMA – Local:
CBDMA and **CPU** in **same** node.

NUMA – Remote:
CBDMA and **CPU** in **different** nodes.

Memory and CBDMA in the same NUMA node.

NUMA

- Influence from CBDMA and CPU NUMA nodes

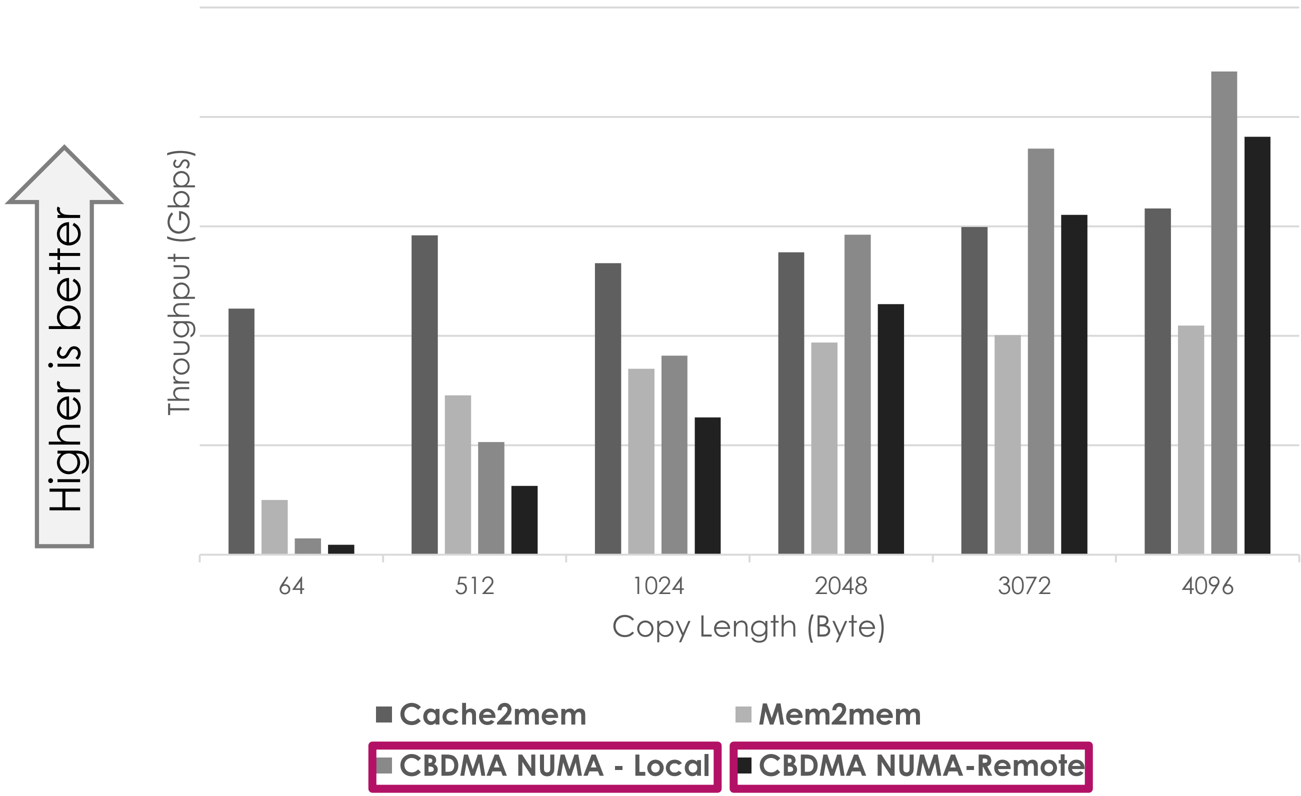


Memory and CBDMA in the same NUMA node.

- CPU and CBDMA in **same** NUMA node **improves** throughput **16% ~ 66%.**

CPU, memory and CBDMA locate ***closer****, CBDMA achieve* ***higher*** *performance.*

Copy Length

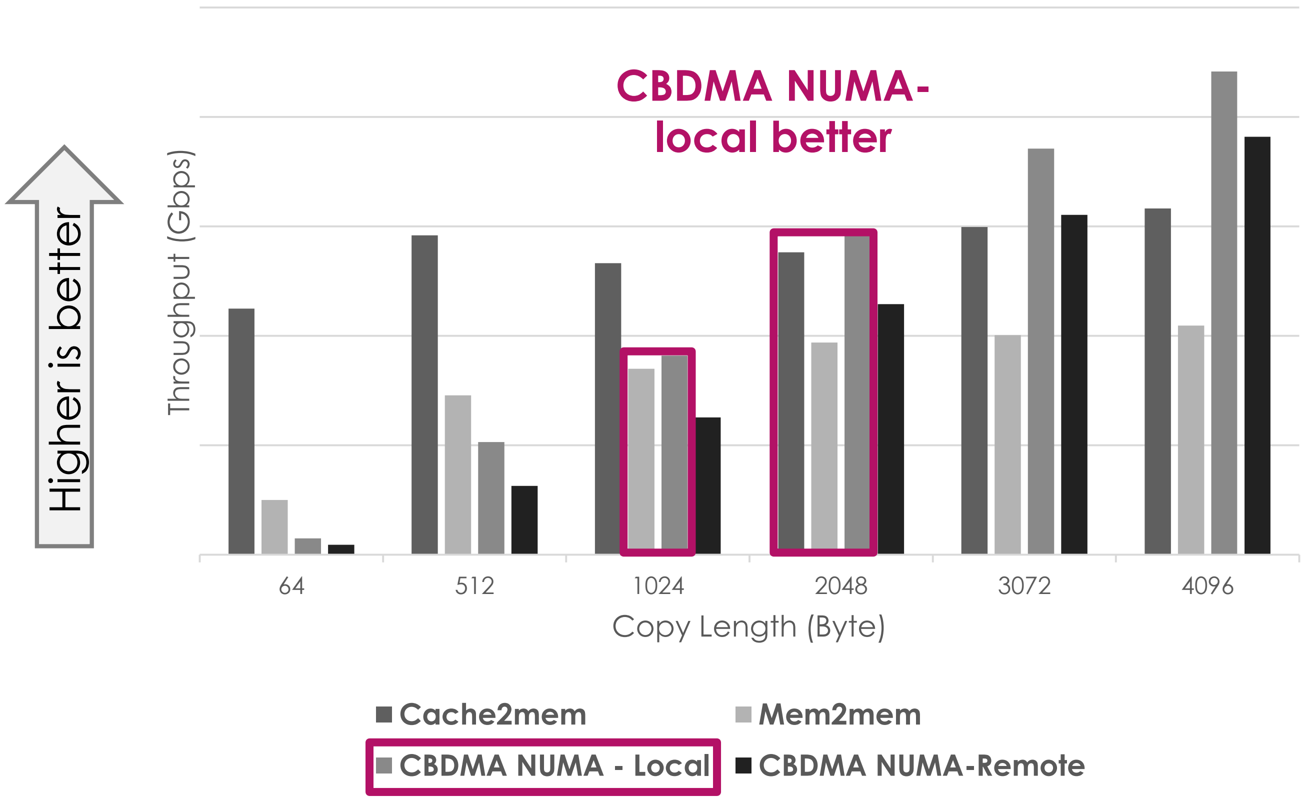


CBDMA NUMA–Local: CBDMA copy & CBDMA and CPU in **same node**.

CBDMA NUMA–Remote: CBDMA copy & CBDMA and CPU in **different nodes**.

Copy Length

- CBDMA NUMA-local vs. CPU

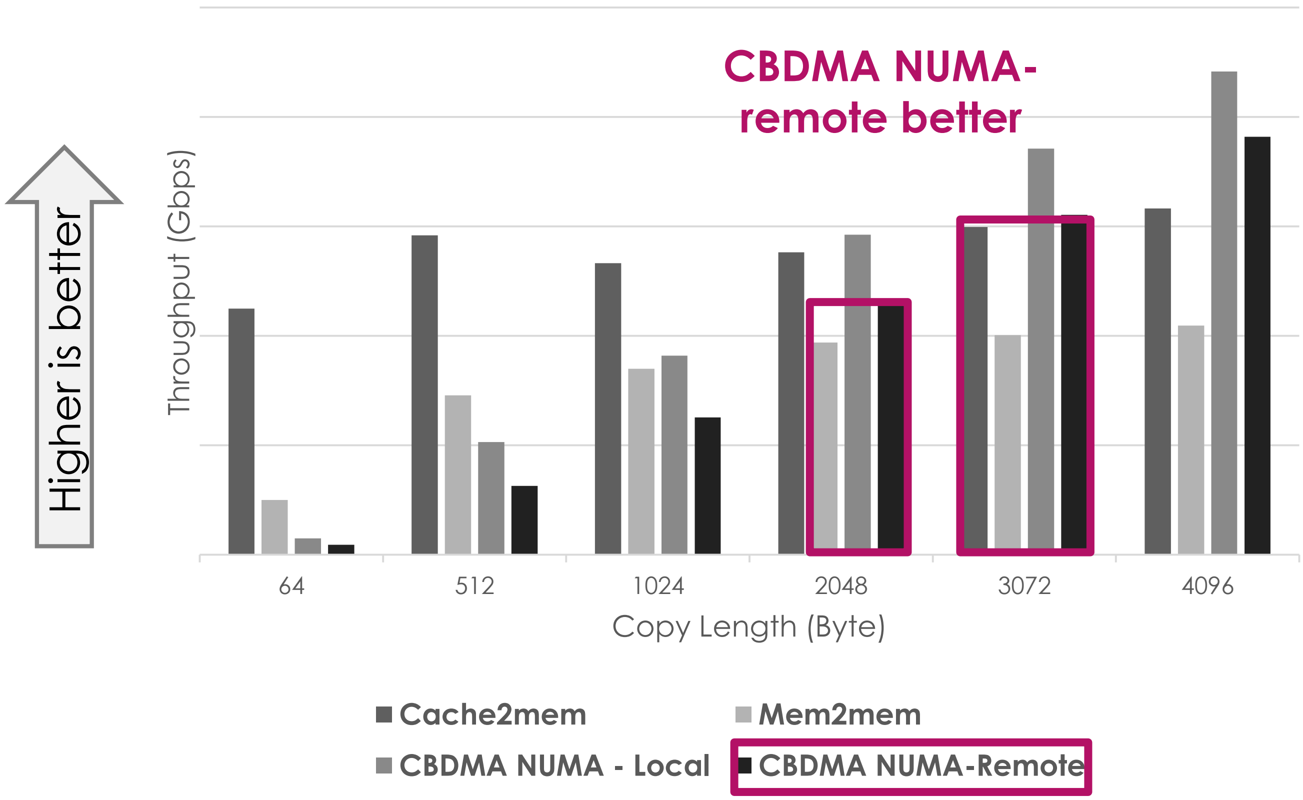


CBDMA NUMA-local better

- When lengths exceed **1024 B and 2048 B**, CBDMA NUMA-local outperforms CPU.

Copy Length

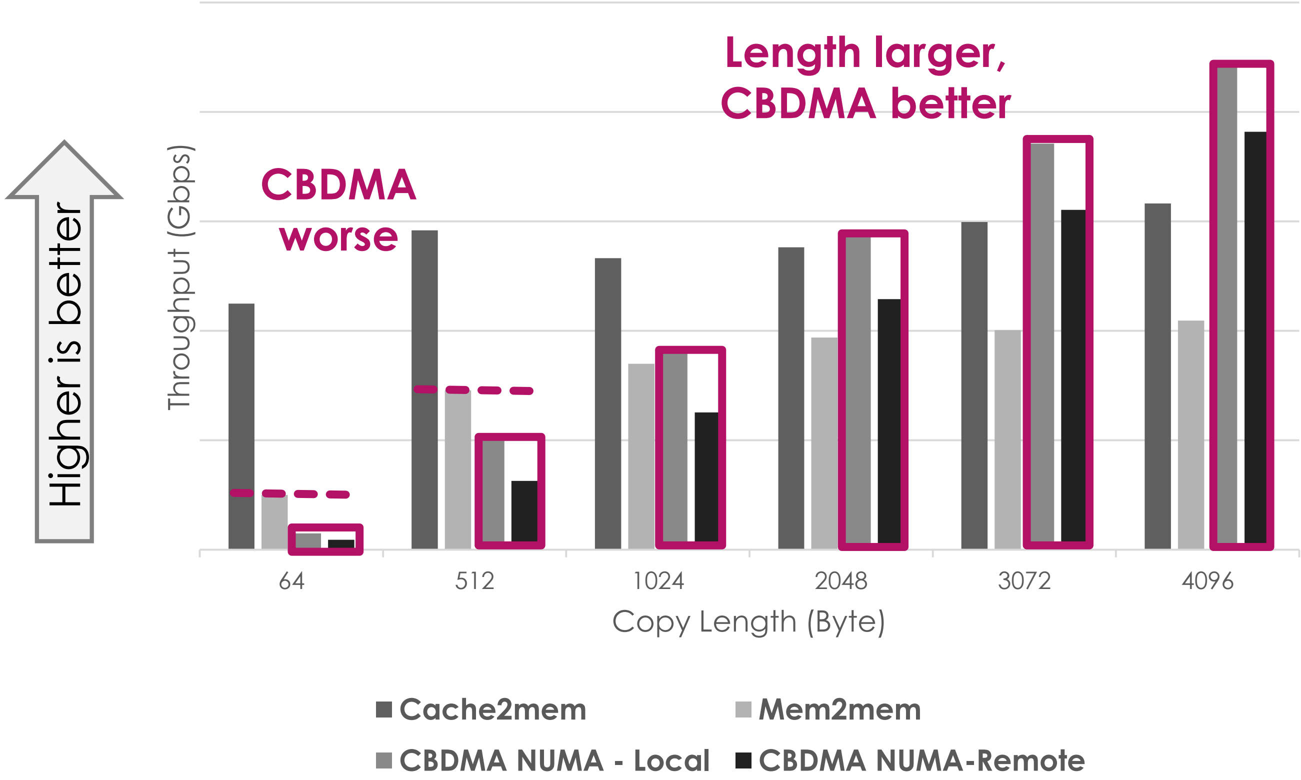
- CBDMA NUMA-remote vs. CPU



- When lengths exceed **2048 and 3072 B**, CBDMA NUMA-remote outperforms CPU.

Copy Length

- CBDMA vs. CPU



- When lengths are smaller than **1024 B**, CPU outperforms CBDMA.

*CBDMA achieves **higher** performance with **larger** copy lengths.*

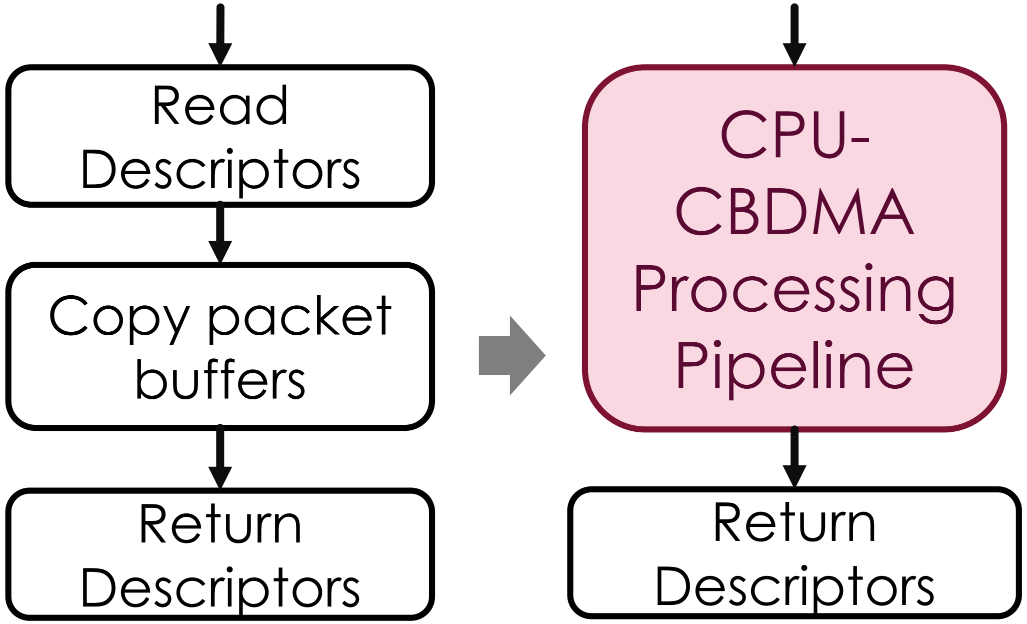
Solutions to Address Challenges

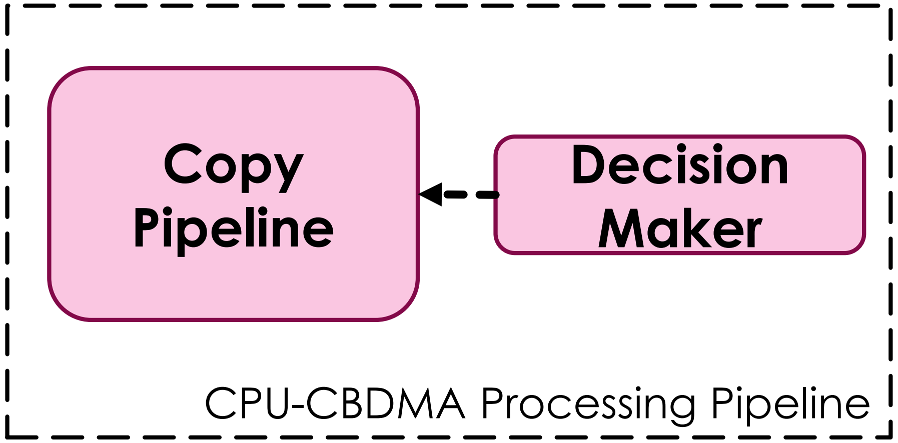
- **NUMA-aware resource assignment scheme**
  - Dynamically assign CPU, memory and CBDMA devices, according to resource status.
  - Working in progress.

- **Increase packet lengths** via enabling **TCP Segmentation Offload** (TSO) and **UDP Fragmentation Offload** (UFO).
  - E.g. 1.5 KB → 64 KB TCP packets

- **Adaptive CPU-CBDMA Pipeline**

Adaptive CPU-CBDMA Pipeline

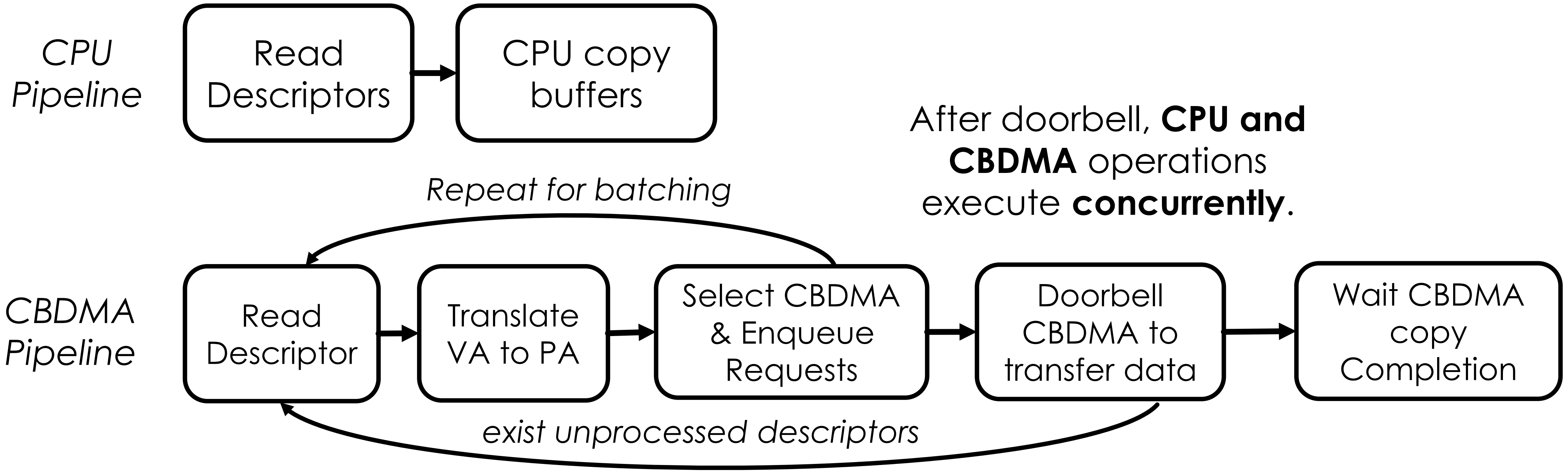




One enqueue/ dequeue operation

Adaptive CPU-CBDMA Pipeline

- Copy pipeline

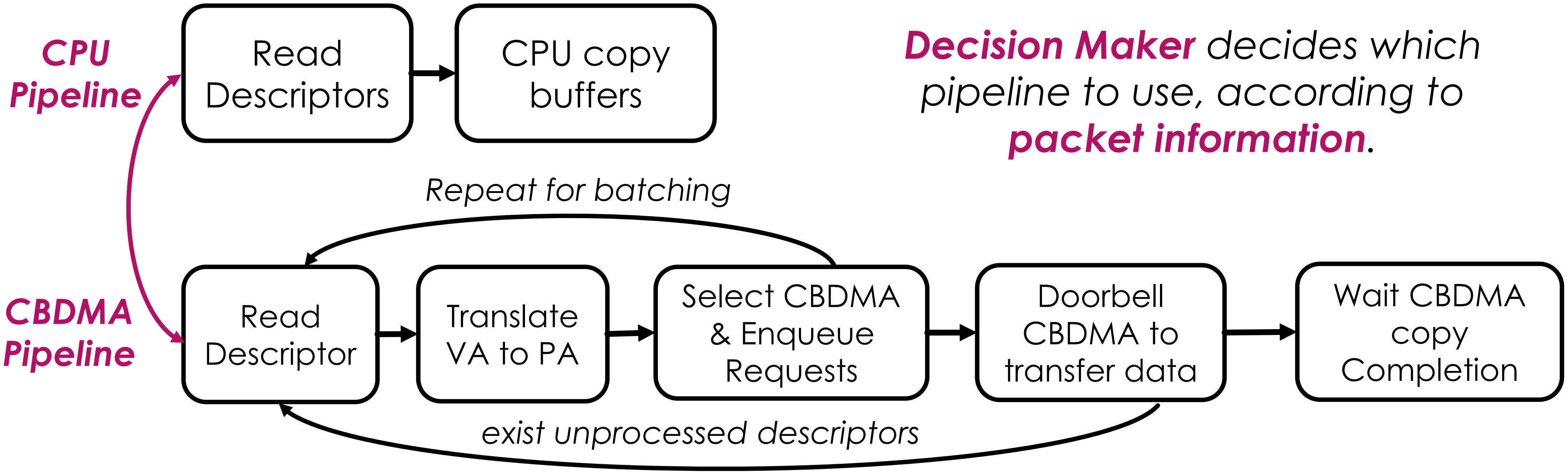


CPU Pipeline
Read Descriptors
CPU copy buffers
Repeat for batching
CBDMA Pipeline
Read Descriptor
Translate VA to PA
Select CBDMA & Enqueue Requests
Doorbell CBDMA to transfer data
Wait CBDMA copy Completion
exist unprocessed descriptors

After doorbell, **CPU and CBDMA** operations execute **concurrently**.

Adaptive CPU-CBDMA Pipeline

- Copy pipeline

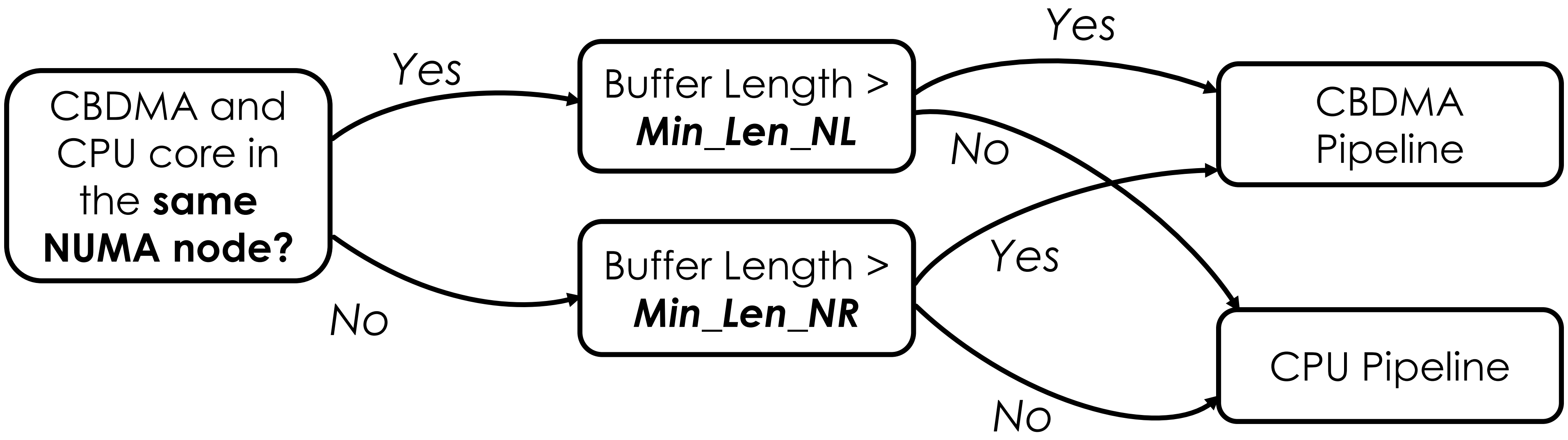


CPU Pipeline
Read Descriptors
CPU copy buffers
Repeat for batching
CBDMA Pipeline
Read Descriptor
Translate VA to PA
Select CBDMA & Enqueue Requests
Doorbell CBDMA to transfer data
Wait CBDMA copy Completion
exist unprocessed descriptors

***Decision Maker** decides which pipeline to use, according to **packet information**.*

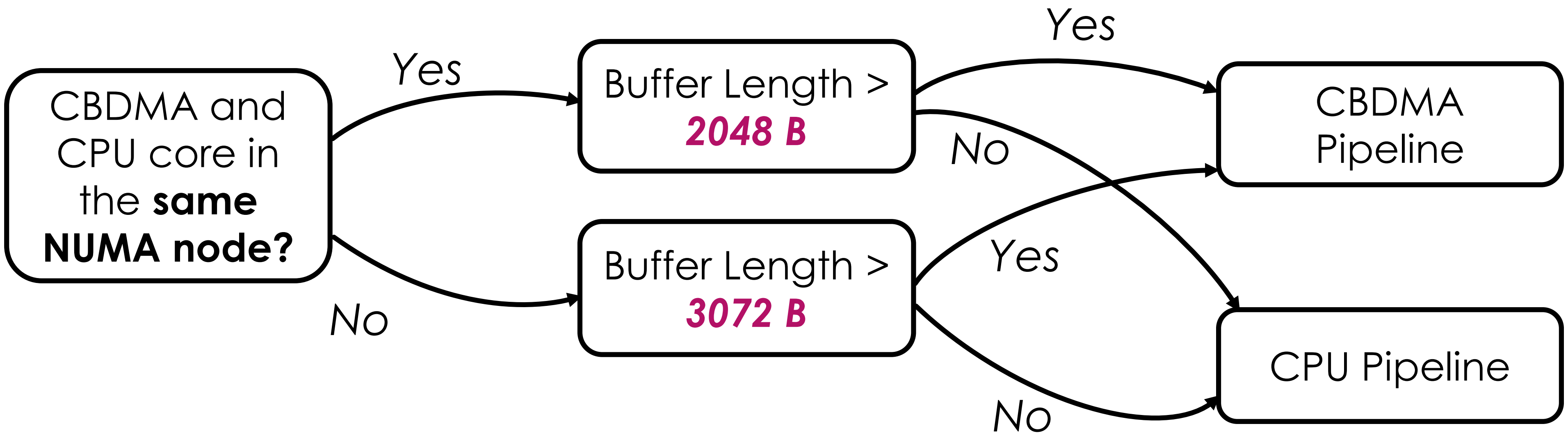
Adaptive CPU-CBDMA Pipeline

- Decision maker


CBDMA and CPU core in the **same NUMA node?**
Yes
No
Buffer Length > ***Min_Len_NL***
Buffer Length > ***Min_Len_NR***
Yes
No
Yes
No
CBDMA Pipeline
CPU Pipeline

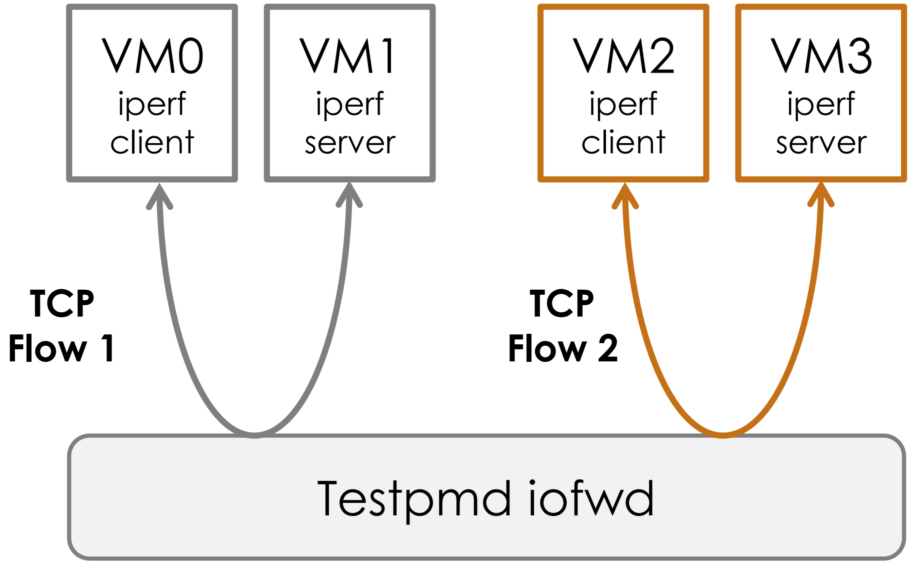
- ***Min_Len_NL*** is the **minimal length** that CBDMA outperforms CPU, when in the **same NUMA node**.
- ***Min_Len_NR*** is the **minimal length** that CBDMA outperforms CPU, when in **different NUMA nodes**.

Adaptive CPU-CBDMA Pipeline


CBDMA and CPU core in the **same NUMA node?**
Yes
No
Buffer Length > ***2048 B***
Buffer Length > ***3072 B***
Yes
No
Yes
No
CBDMA Pipeline
CPU Pipeline

- Set *Min_Len_NL* and *Min_Len_NR* to 2048 and 3072 bytes.

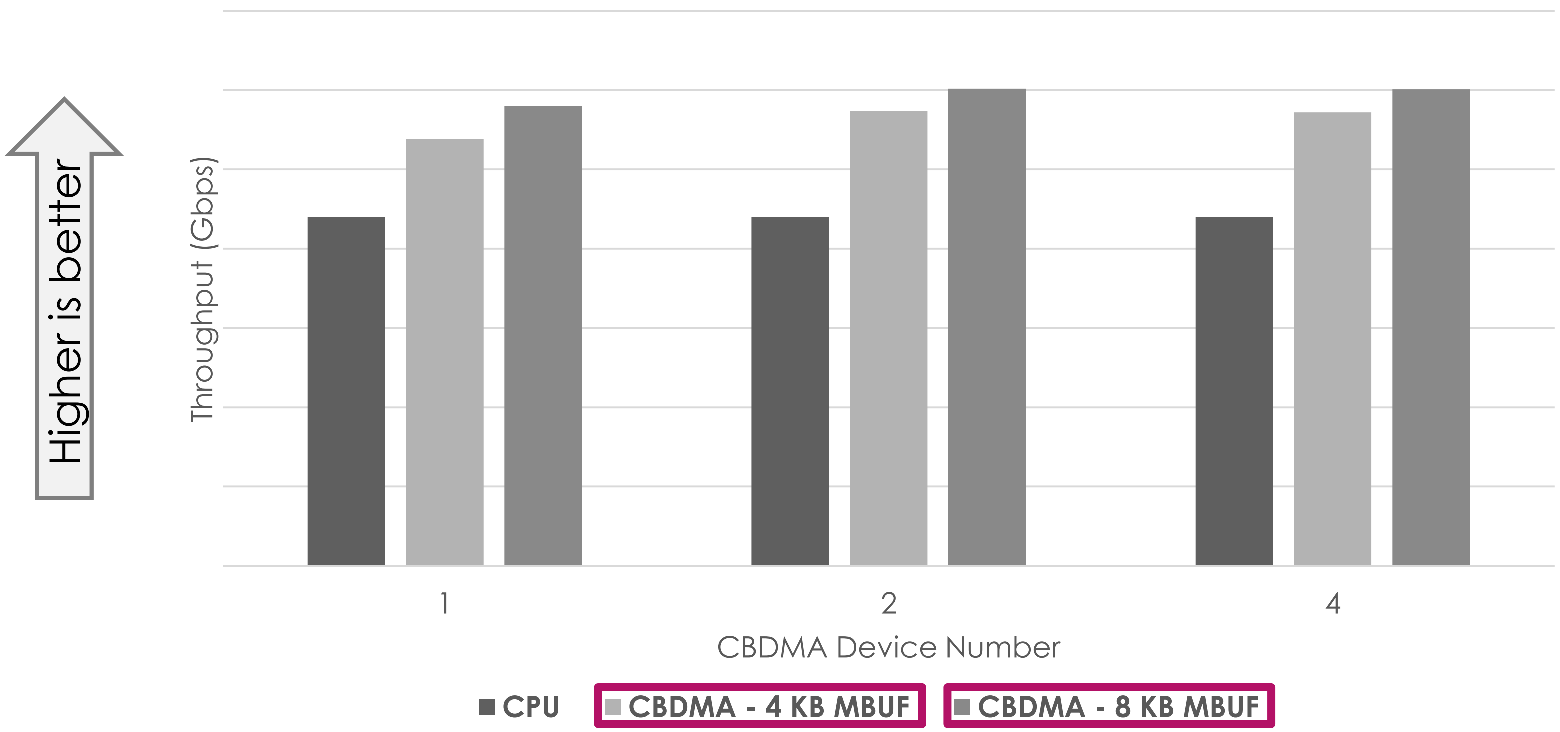
Experiment



CPU	Intel(R) Xeon(R) Platinum 8180 CPU @ 2.50GHz
Testpmd Information	**1 core**
VM Information	**4 cores pre VM** **1GB Huge-page** **Enable TSO** 1 queue
Iperf	**TCP packet size is 64 KB**
CPU cores, CBDMA and memory locate in NUMA node 0.	

- Use 1 GB huge-page to mitigate the address translation overhead, i.e. GPA to HPA.

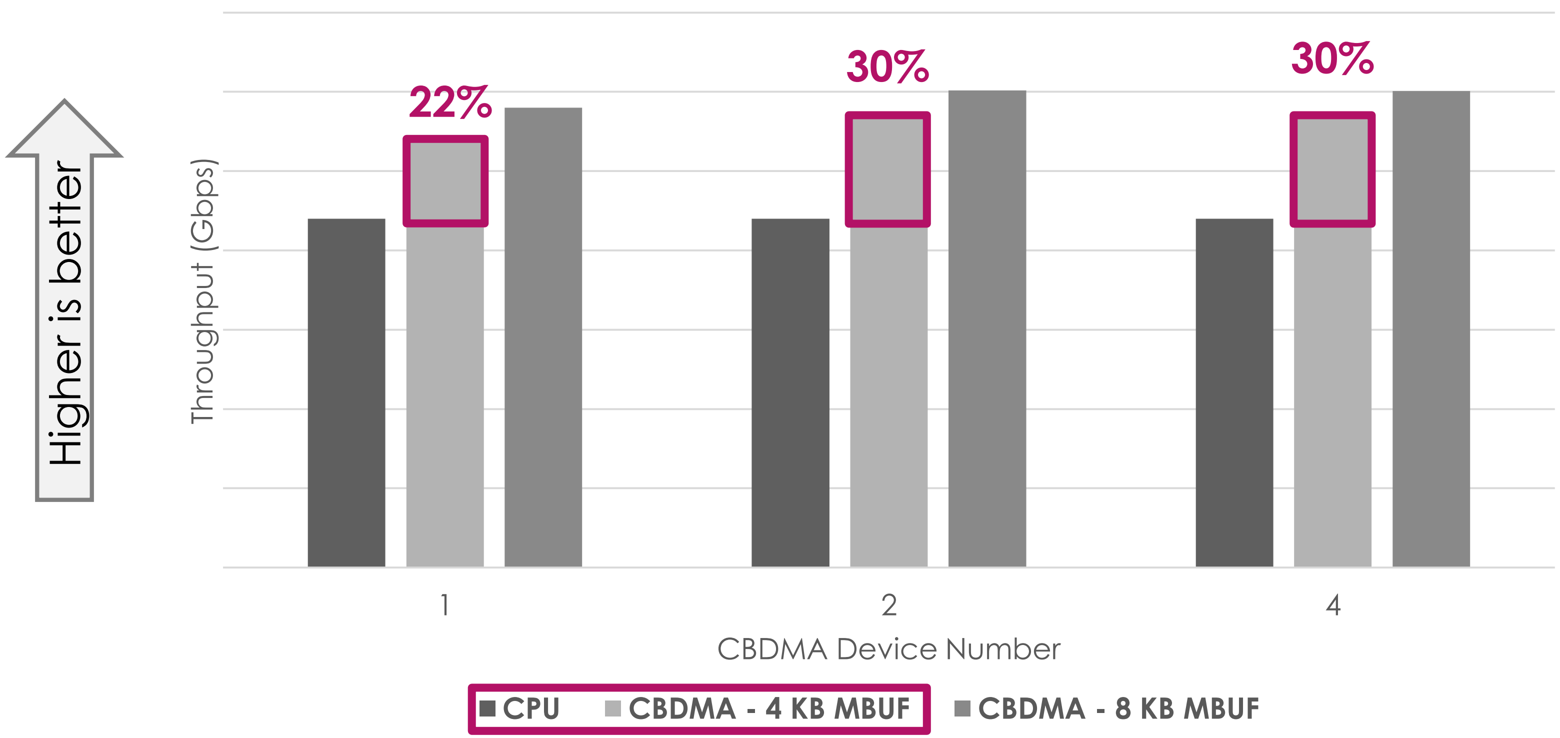
Results



CBDMA – 4 KB MBUF:
Testpmd mbuf size is 4 KB.

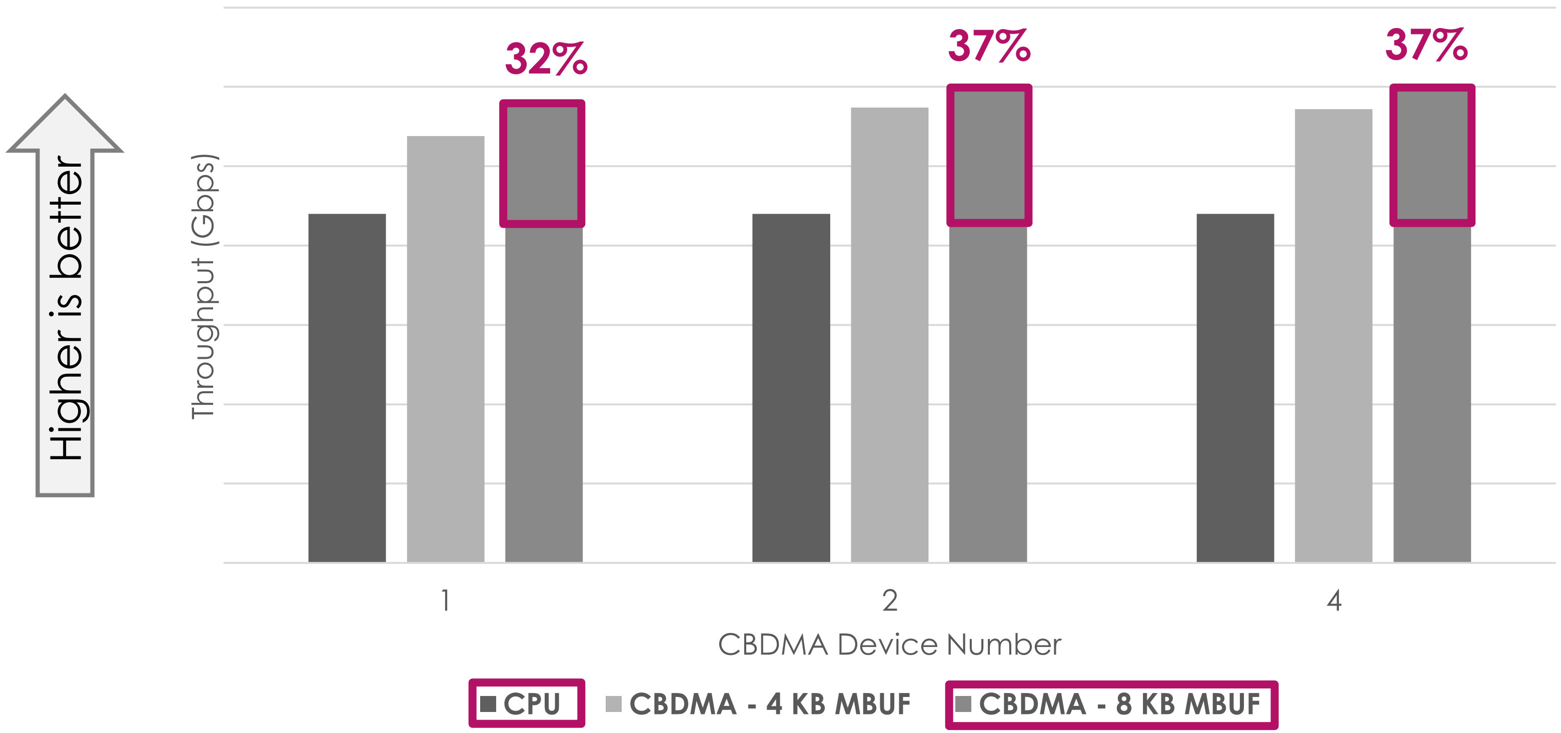
CBDMA – 8 KB MBUF:
Testpmd mbuf size is 8 KB.

Results



- Using 4 KB mbuf, CBDMA improves throughput up to 30%.

Results



CBDMA ***improves*** *performance up to* ***22% and 37%.***

- Using 8 KB mbuf, CBDMA improves throughput up tp 37%.

Thanks

jiayu.hu@intel.com