# DPU-Bench: A New Micro-Benchmark Suite to Measure the Offload Efficiency of SmartNICs


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(Paper: DPU-Bench: A Micro-Benchmark Suite to Measure Offload Efficiency Of SmartNICs

B. Michalowicz, K. Suresh, H. Subramoni, DK Panda, and S. Poole, Practice and Experience in Advanced Research Computing 23, Jul 2023)

# Breakdown

- Introduction, Problem Statement, Motivation
- Design Choices
- Implementation
- Experimental Results
- Conclusion and Future Work

# Problem Statement: We Need a New, DPU-Aware Microbenchmark Suite

- Already have plenty of Suites: OMB, IMB, mpiBench, OpenHPCA, etc.
  - NONE are DPU-Aware!
- Previous works: Utilize DPUs to offload in the context of an MPI-library, for specific apps, or in the context of Deep Learning, but no micro/benchmarks!
- SmartNICs are becoming popular: NVIDIA BlueField, AMD Pensando, Marvell etc.
- What algorithm is the “best” to offload to a DPU? Can we design a microbenchmark suite to measure the offload potential achieved from placing communication to the DPU?

# Design Choice: Running at the IB-Verbs Level

- Running at the MPI level is bottlenecked by progress on the host
  - Naively offloading MPI-level ranks in, e.g., MPI_Ialltoall could create a bottleneck
  - Host issues MPI_Isends to a DPU process  needs to check message progress from host AND DPU sides
- Running over IB-Verbs:
  - Closer to the hardware
  - DPU issues all RDMA operations – host/CPU is not involved
    - No need for asynchronous progress on the host

# General Breakdown of DPU-Bench benchmarks (1/2)

- At initialization:
  - Exchange of metadata for RDMA Read/Write ops
    - lkeys, rkeys, buffer addresses, QP numbers, etc.
- Runtime:
  - Step 1: Do Pure-Host execution  obtain reference time for dummy compute.
  - Step 2: Offload communication to DPUs while the host side does compute
  - Step 3: Measure Offload Efficiency

Listing 2. General Approach to Each Benchmark

Initialization

```
/* Setup - assume options are
passed in through CLI */
MPI_Init(...);
/*Record-keeping struct*/
global_struct g;
/* Every process makes its own memory region
* which makes the needed rkeys
*/
setup_ib_counters(&g, msg_size,
    num_workers, num_host_procs);
/* Exchange of rkeys between processes */
MPI_Allgather(...);
/* Exchange of RDMA Buffer addresses */
MPI_Allgather(...);
```

Step 1

```
create_sends_and_recvs_pure_host();
run_pure_host(); //gives reference time
```

Step 2

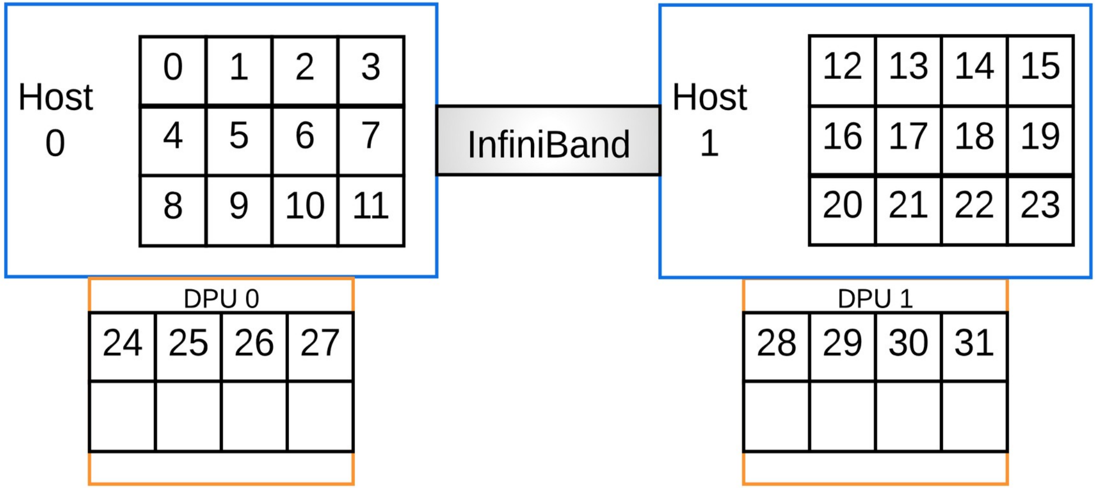
```
create_sends_and_recv_worker_procs();
if (proc_is_on_dpu()){
/* IB-level RDMA-operations */
    run_benchmark();
}else{
    perform_compute_on_host(ref_time);
}
```

Step 3 + Cleanup

```
MPI_Barrier(MPI_COMM_WORLD);
obtain_max_of_lat_and_comp();
compute_overlap();
cleanup();
MPI_Finalize();
```

# General Breakdown of DPU-Bench benchmarks (2/2)

- Assumptions made about MPI runtime
  - Use of a block-style hostfile – helps with organization of config files
  - Higher-numbered ranks are placed on the DPU
  - Multiple Program, Multiple Data (MPMD) mode in an MPI library – required for dealing with CPU/DPU configurations



# Collective patterns in this benchmark suite

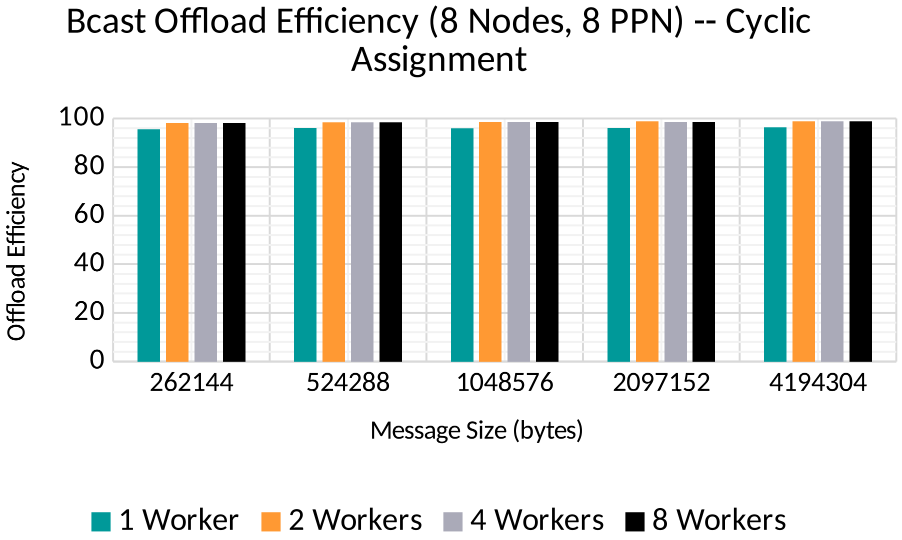
- Non-personalized one-to-all: Direct/Linear Broadcast
- Personalized all-to-one: Direct/Linear Gather
- Non-Personalized all-to-all: Direct/Linear Allgather with a single “root” worker
  - Later slides: Improve upon this to utilize multiple workers to demonstrate more efficient staging
- Will only show a subset here

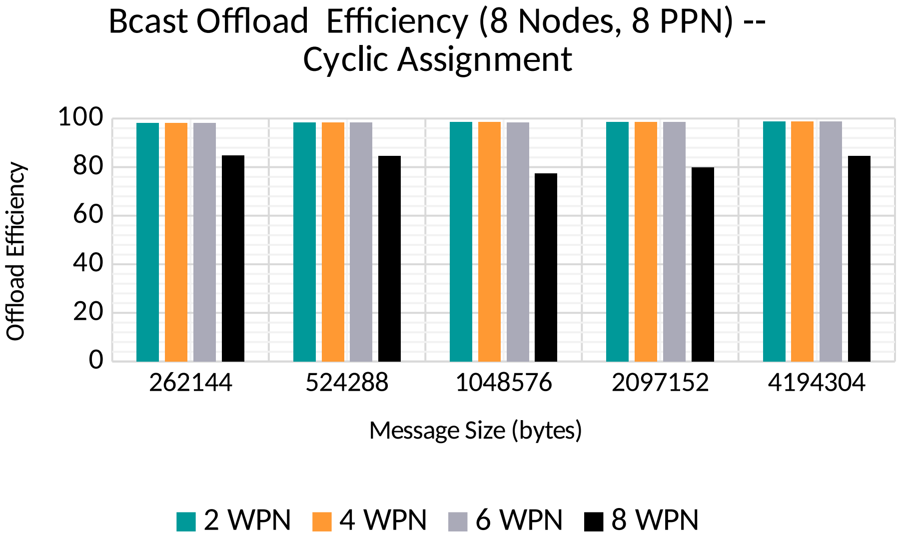
# Experiments Performed

- 8 nodes, 8 PPN on host
- Ranging from 1 worker (total) to 8 WPN on 8 DPUs (64 total workers)
  - Powers of 2: 1, 2, 4, 8…
- Study message sizes from 256K to 4 MB
- Offload Efficiency:

  (reference_time/max(pure_comm, compute)) * 100
- Show Offload efficiency results for broadcast, gather, and allgather with both cyclic and block work

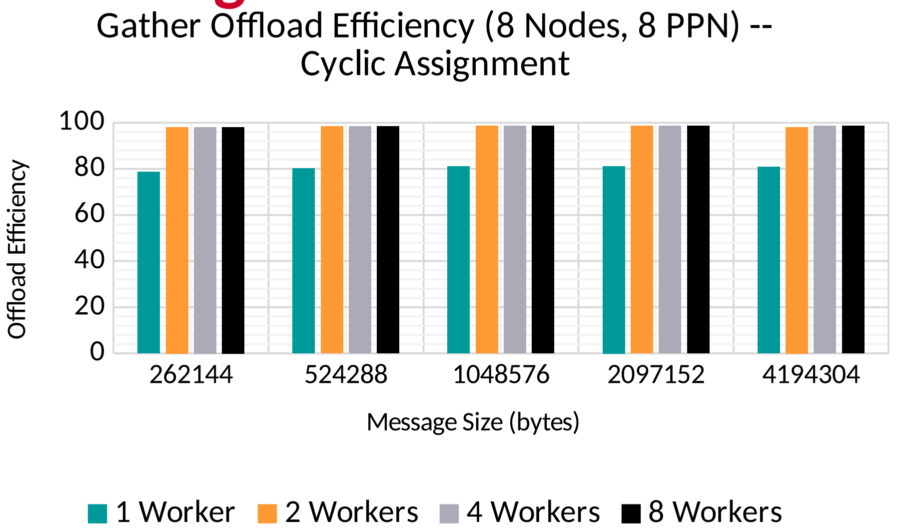
# Offload Efficiency Results: Broadcast – Cyclic Work Assignment

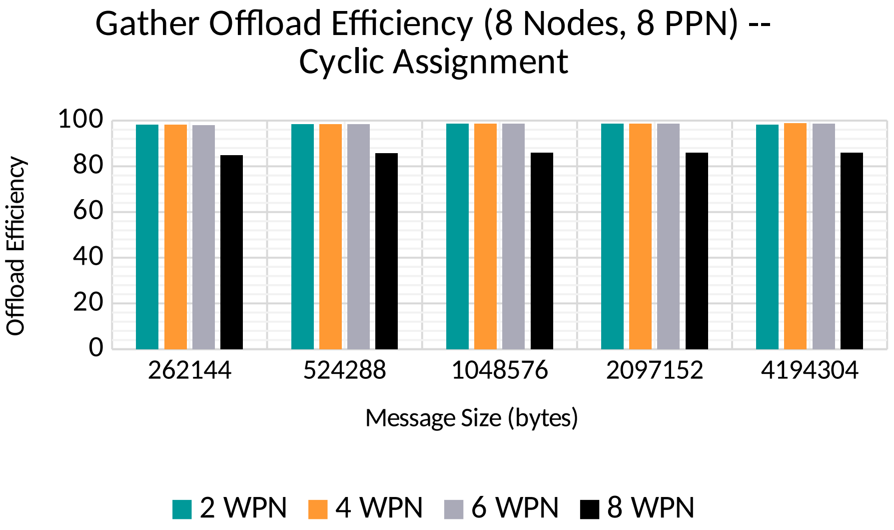



- General takeaway: 1 WPN is a “sweet spot” for maximum efficiency
- 8 WPN: Incurs overhead from the BF-2’s single memory controller and limited cache sizes

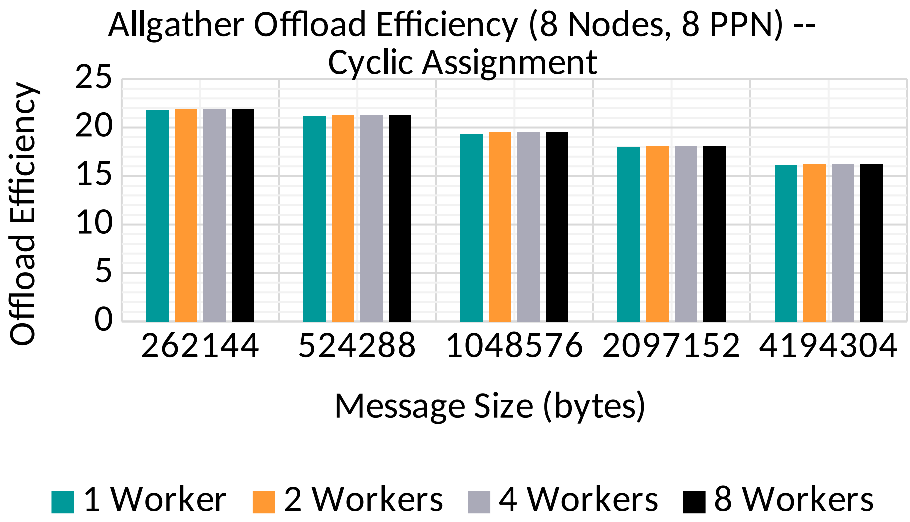
# Offload Efficiency Results: Gather – Cyclic Work Assignment

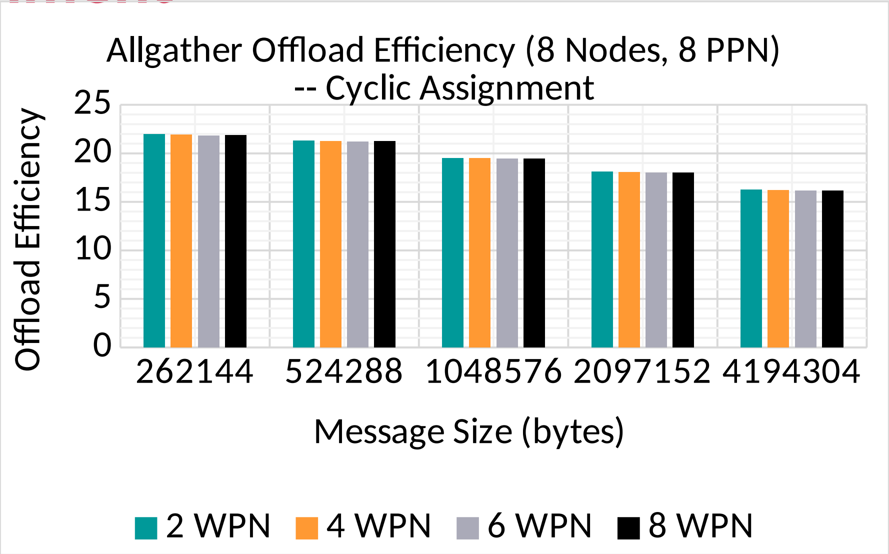



- 1 Worker: Adds overhead of an "intermediate" process to write to the root
- Similar trends to the "Broadcast" results

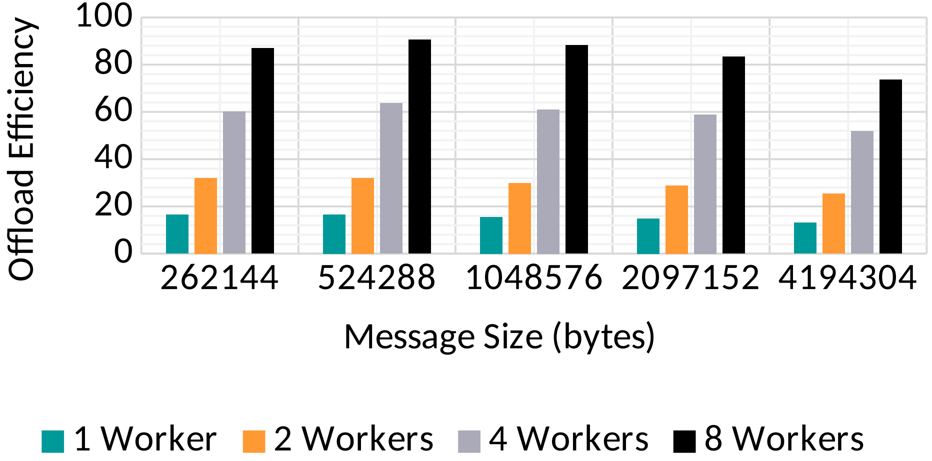
# Offload Efficiency Results: Allgather (Single-Root Worker) – Cyclic Work Assignment

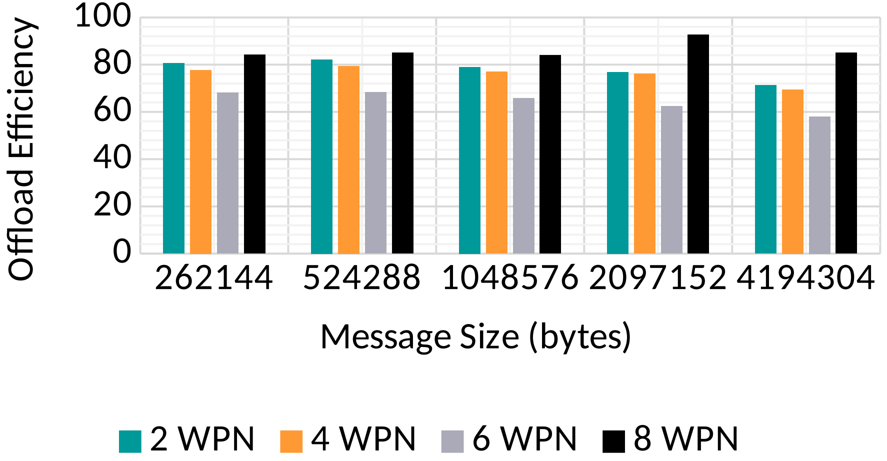



- Gather and Broadcast placed back-to-back incurs massive overhead
- Slight degradations with increase in message size

# Offload Efficiency Results: Allgather (Efficient Use of Multiple Workers – Cyclic Work Assignment)




- 1 worker (total) to 1 WPN: 1.3-2X improvement in efficiency with the addition of workers
- 2 WPN – 6 WPN: Predictable trend of decreasing offload efficiency

# Conclusion/Future Work

- Introduction of a new, DPU-Aware Microbenchmark Suite
- Explored three communication patterns/algorithms
- Initial Release planned for the near future
- Generalize the benchmarks to other programming models
- Generalize the work to other SmartNICs

# Thank You!

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