An Update on the Progress towards Distributed OpenMP

Atmn Patel, Northwestern University
September 30th, 2022

Acknowledgements

We gratefully acknowledge the computing resources provided and operated by the Joint Laboratory for System Evaluation (JLSE) at Argonne National Laboratory.

Part of this research was supported by the Exascale Computing Project (17-SC-20-SC), a collaborative effort of two U.S. Department of Energy organizations (Office of Science and the National Nuclear Security Administration) responsible for the planning and preparation of a capable exascale ecosystem, including software, applications, hardware, advanced system engineering, and early testbed platforms, in support of the nation's exascale computing imperative.

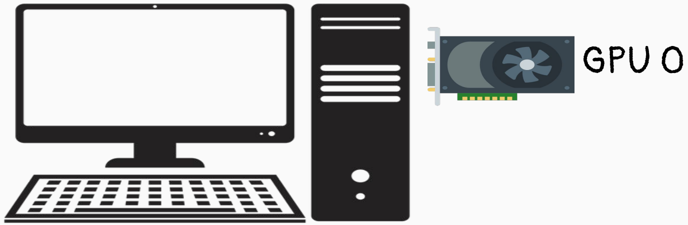
Part of this research was supported by the Lawrence Livermore National Security, LLC ("LLNS") via MPO No. B642066.

Credits

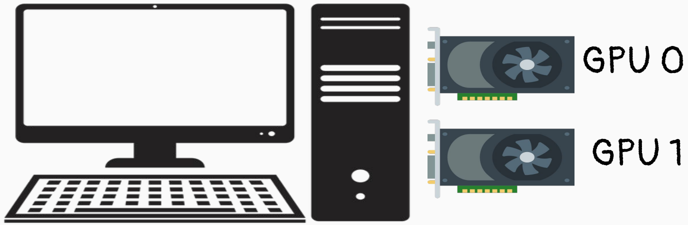
This research direction was initiated under the supervision of Johannes Doerfert at Argonne National Lab.

Since the initial work, the work has been taken over by the Exasca||ab at Stony Brook University.

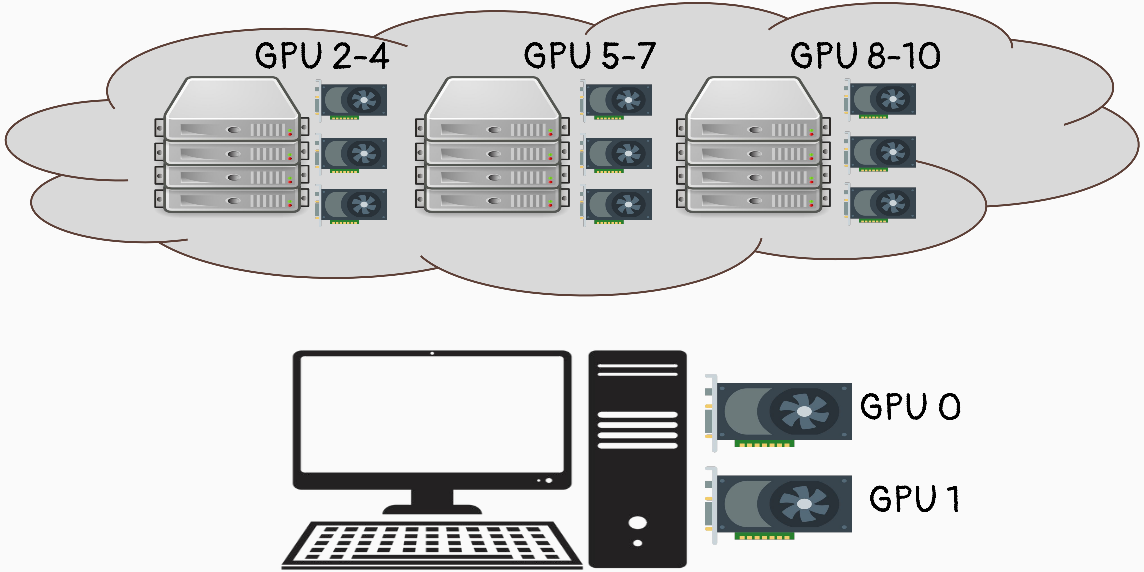
OpenMP Offload



Multi-GPU OpenMP Offload



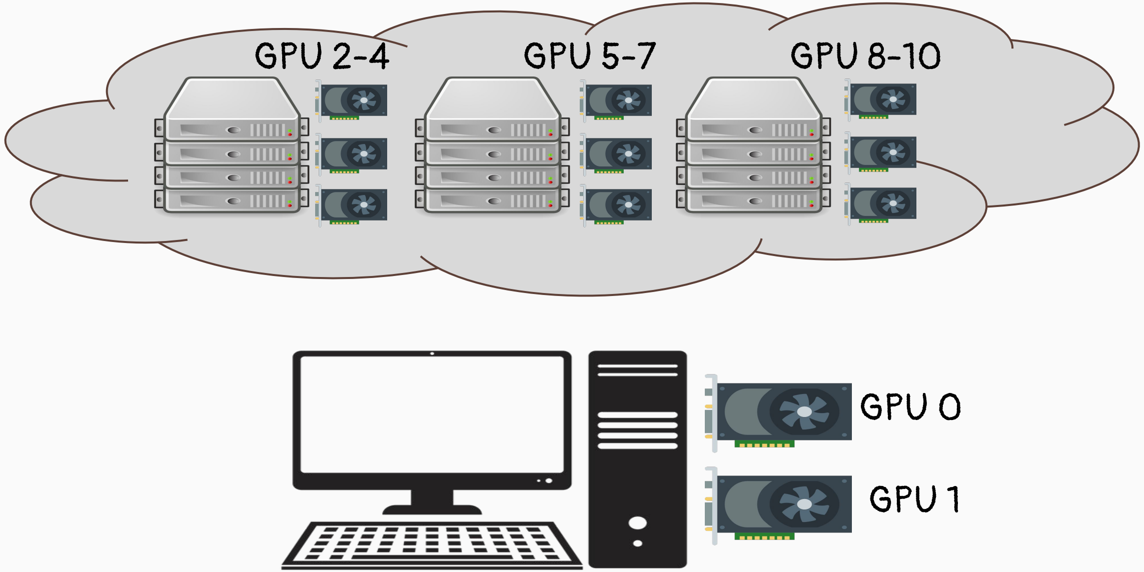
Remote Multi-GPU OpenMP Offload



Remote Multi-GPU OpenMP Offload

distributed environment ⟶

- non-unified memory +
- non-unified address space



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Benefits:

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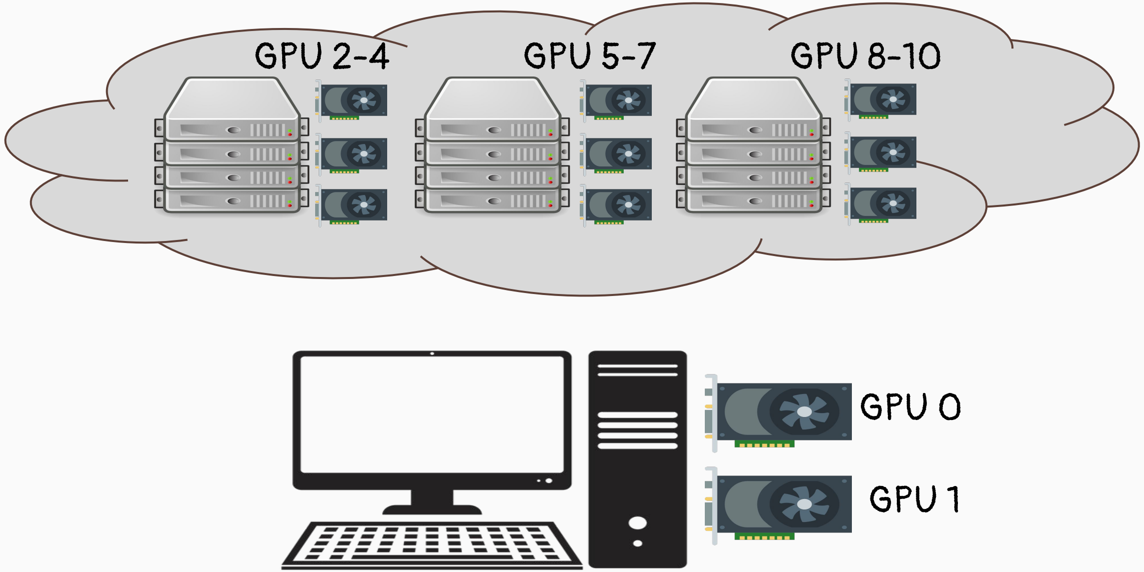

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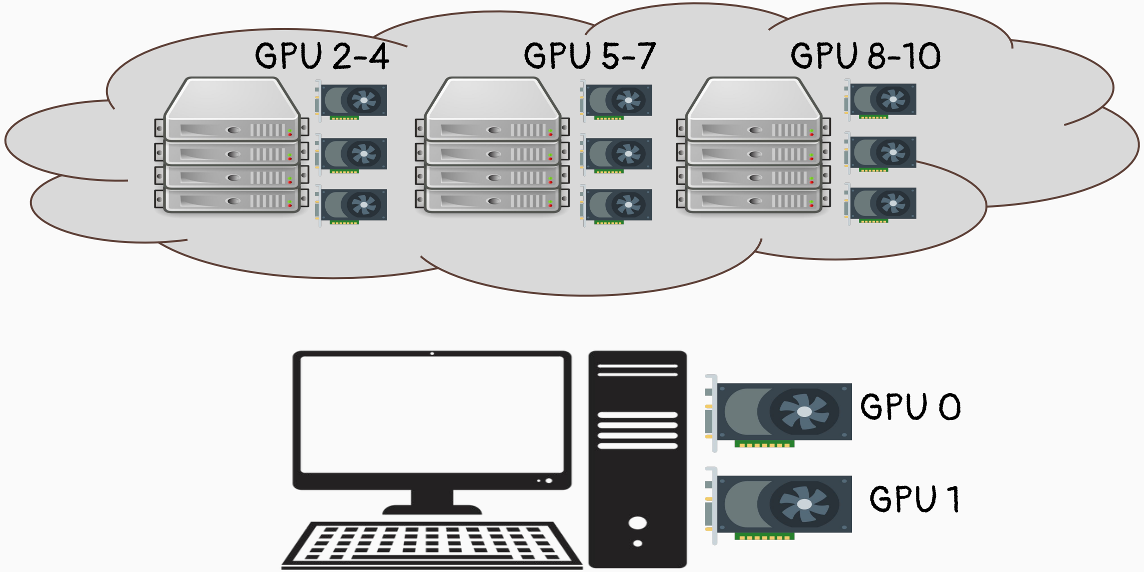

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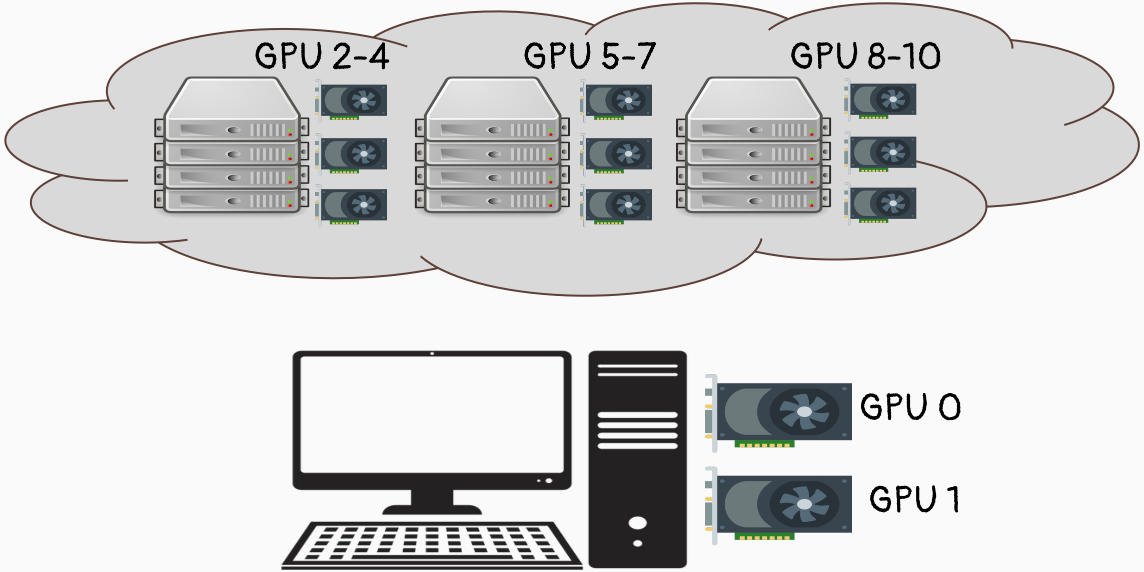

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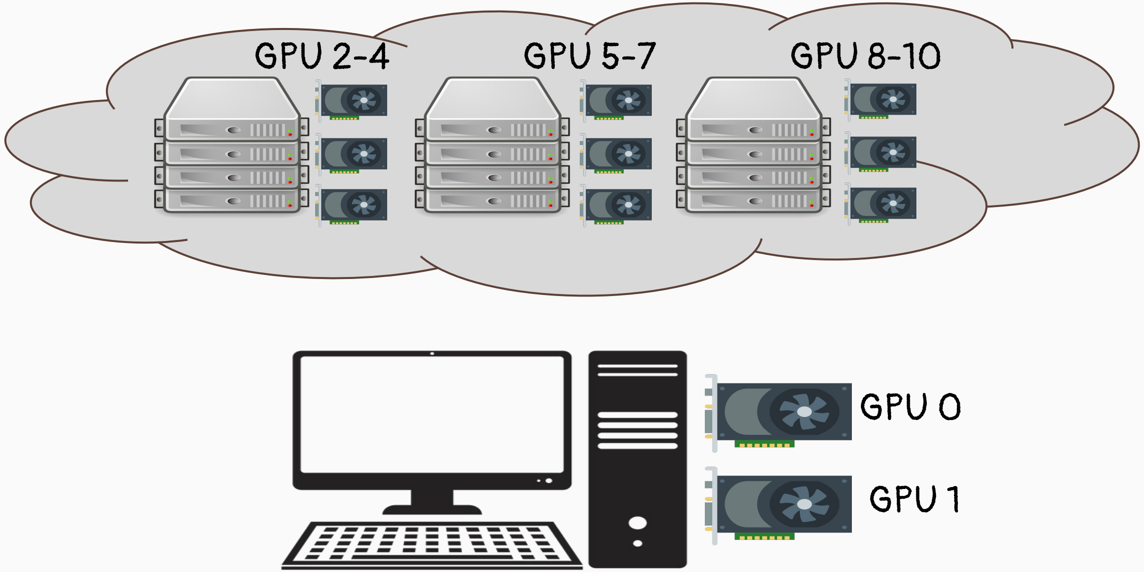
- - limited to the “host-centric” model



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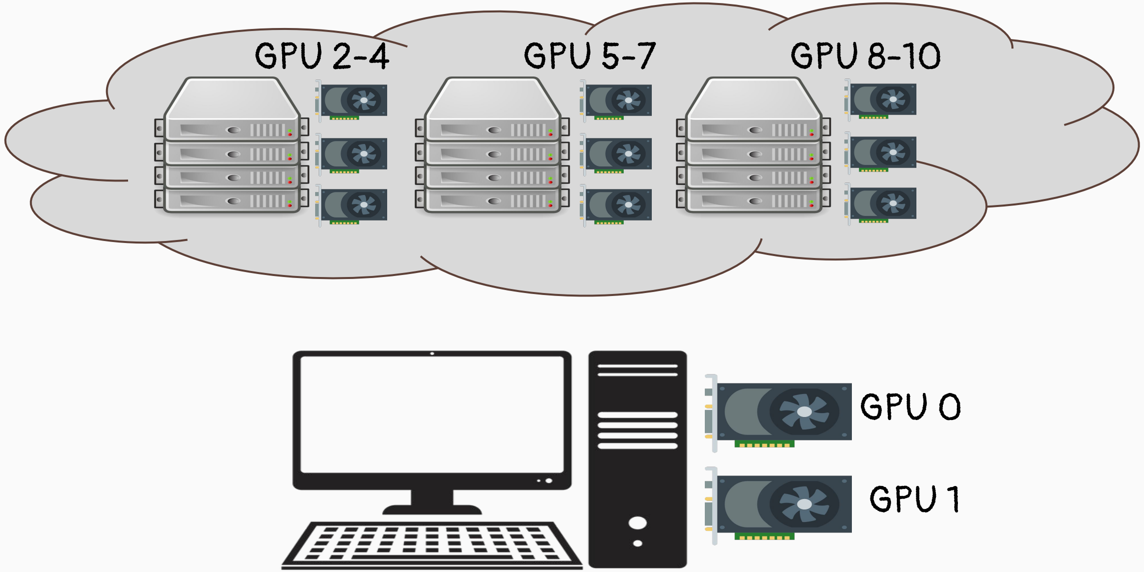

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Drawbacks:

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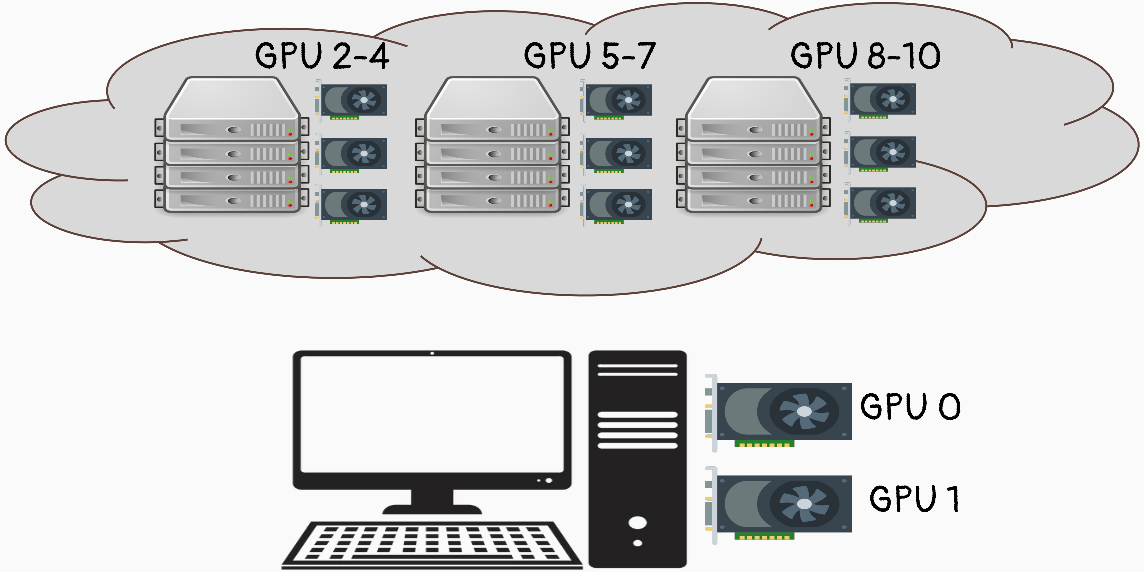

***Remote OpenMP Offloading* offers distributed compute resource usage through a *single, coherent parallel programming model*.**

Implementation

Slide originally presented at LLVM-Dev Meeting 2020 by Johannes Doerfert https://youtu.be/M0DrhQbjrro

OpenMP in LLVM

https://openmp.llvm.org/docs

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Clang

OpenMP Parser

OpenMP Sema

OpenMP CodeGen

OpenMP runtimes

libomp.so
(classic, host)

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libomp.so (classic, host)

libomptarget + plugins (offloading, host)

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OpenMP-IR-Builder

frontend independant OpenMP LLVM-IR generation

favor simple and expressive LLVM-IR

reusable for non-OpenMP parallelism

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Flang / Clang	OpenMP-IR-Builder	OpenMP-Opt	OpenMP runtimes
OpenMP Parser	frontend independant OpenMP LLVM-IR generation	interprocedural optimization pass	libomp.so (classic, host)
OpenMP Sema	favor simple and expressive LLVM-IR	contains host & device optimizations	libomptarget + plugins (offloading, host)
OpenMP CodeGen	reusable for non-OpenMP parallelism	run with -O1 and higher	libomptarget-nvptx (offloading, device)

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Remote OpenMP Offloading (Plugin)

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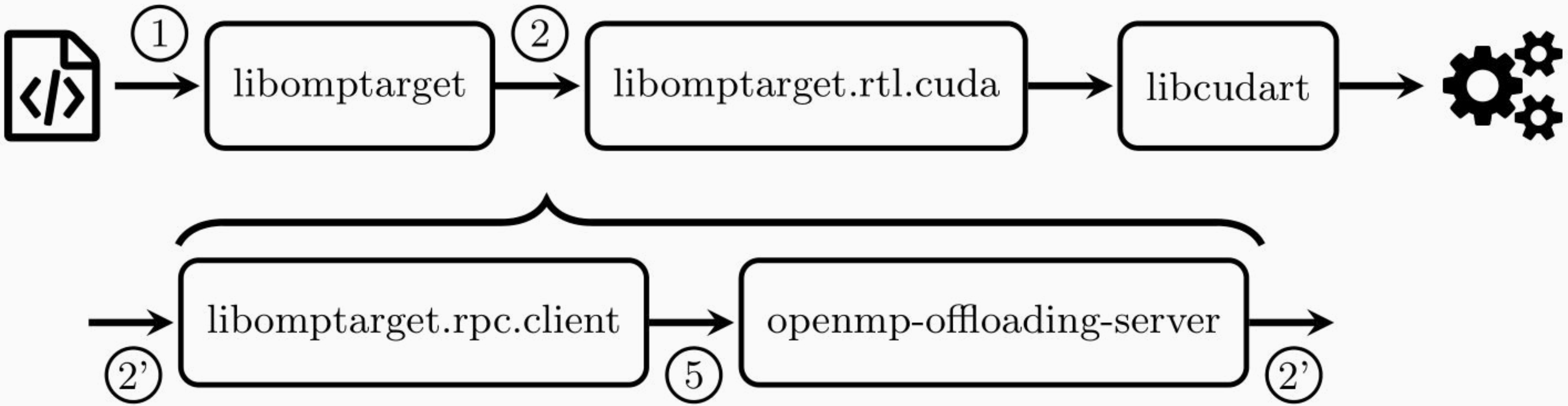
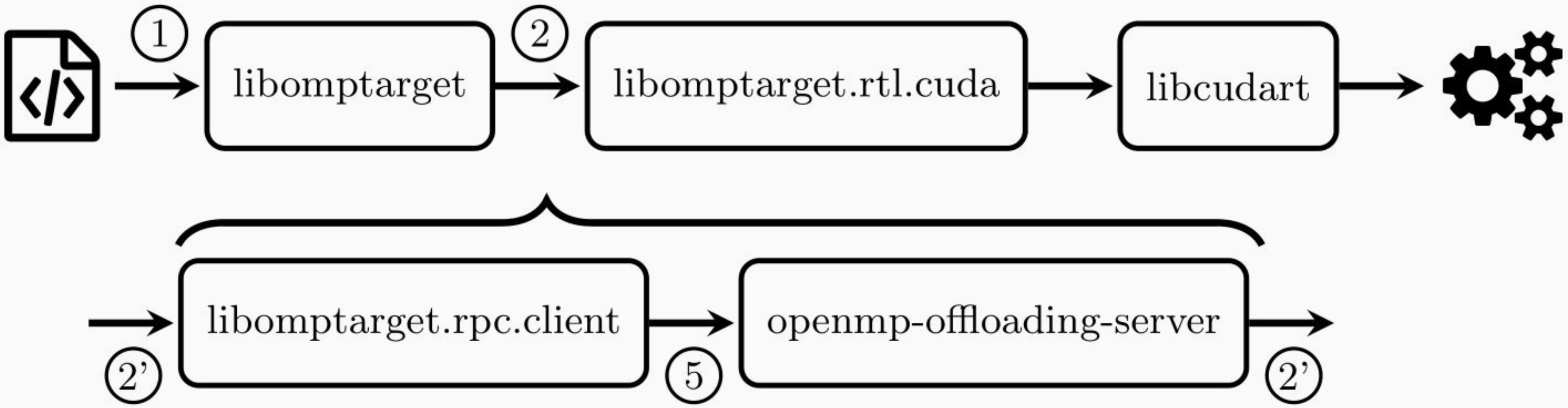


Remote OpenMP Offloading (Plugin)



* interface (2') is (2) with two optional API functions exposed by the *remote* plugin.

Networking Backends

gRPC (may be deprecated very soon)
(google's Remote-Procedure-Call)

- \+ many out-of-the-box features: thread pools, concurrency, compression, …
- ● optimized for small messages (< 2 MB)
- \- tied to (google's) protobuf
- \- general purpose & little customization e.g., for compression, specialized networks and access kinds

UCX
(Unified Communication X)

- \+ highly configurable (RMA, AMO, Tag Matching, Active Message, Stream, …)
- \+ network layer aware (IP over InfiniBand)
- \- Using MPICH directly has better performance for large messages for now

Implementation Notes

It has been only tested on NVIDIA GPUs, but it should extend to any accelerator targeted by LLVM.

It is known to work from x86 and ARM to remote GPUs, SmartNIC CPU and GPUs, etc.

The upstream has been broken for a while, but many performance updates + fixes are in-flight from Exasca||ab.

Stony Brook has been working on a more efficient implementation, where they:

- Use CUDA-Aware Communication
- Improved NUMA Awareness through some fun techniques
- Presented at IWOMP this week

Evaluation

RSBench/XSBench

- Monte Carlo simulation codes
- particle transport in reactors
- available for single-GPU OpenMP offload
- extended to multi-GPU OpenMP offload (easy to map)
- weak scaling in the Google cloud (4 nodes, 1 NVIDIA T4 GPU each)
- strong scaling on ThetaGPU (15 nodes, 8 NVIDIA A100 GPUs each)

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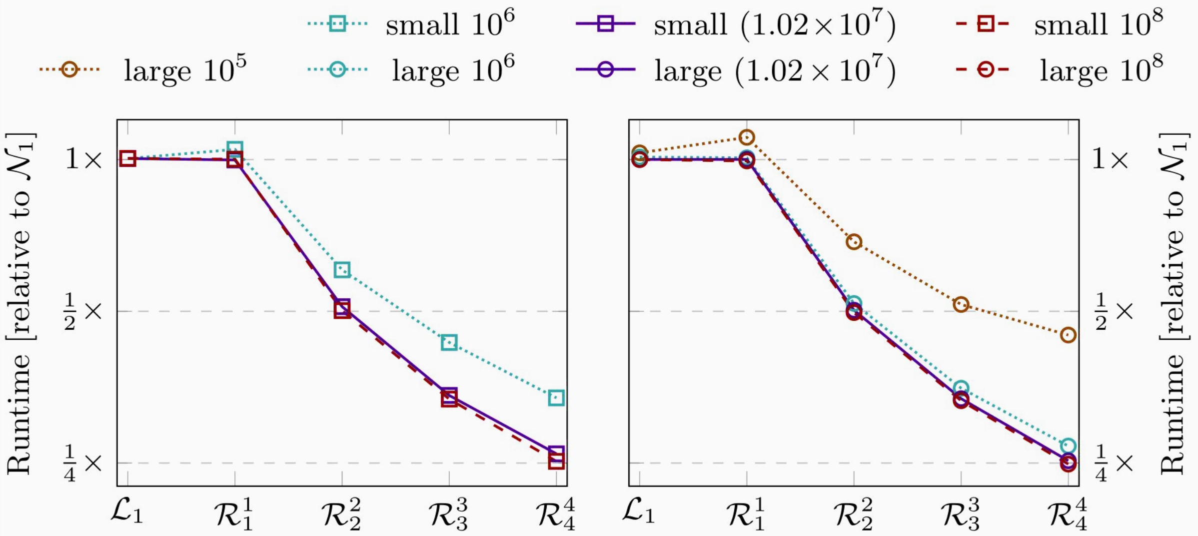
RSBench on Google Cloud



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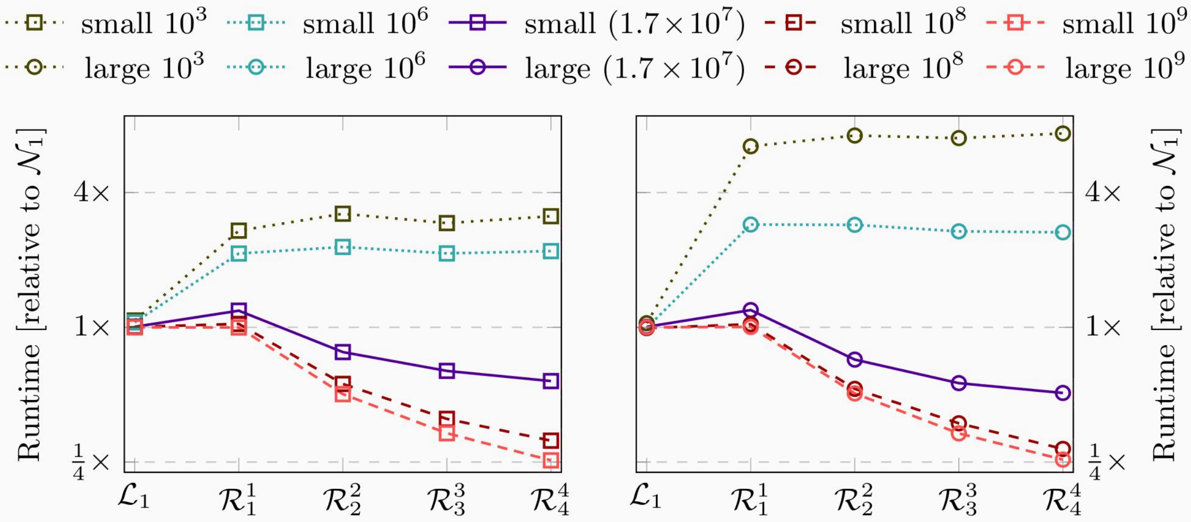

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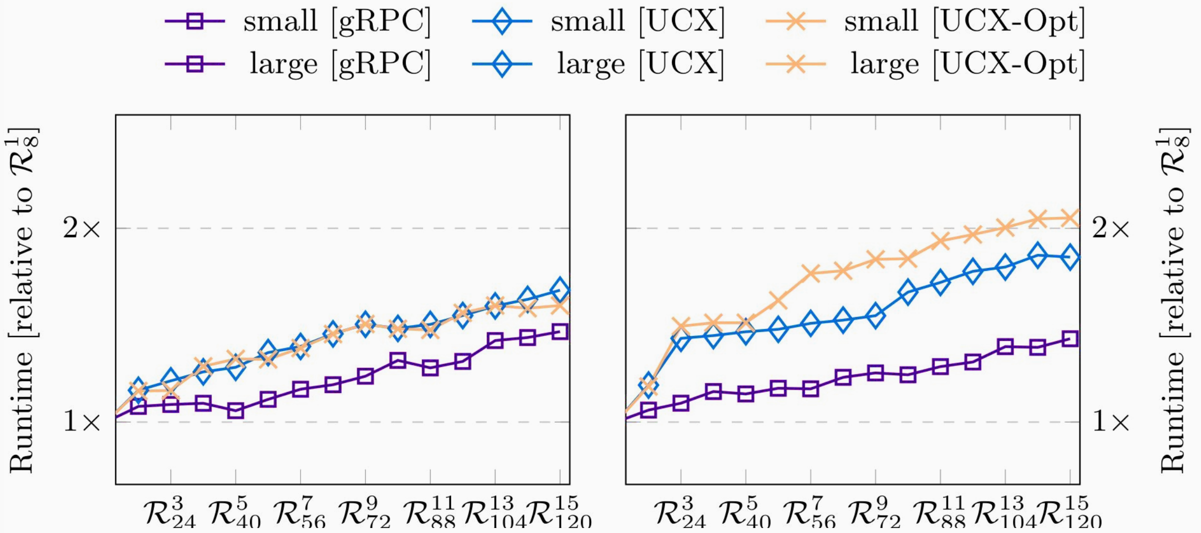
RSBench on ThetaGPU



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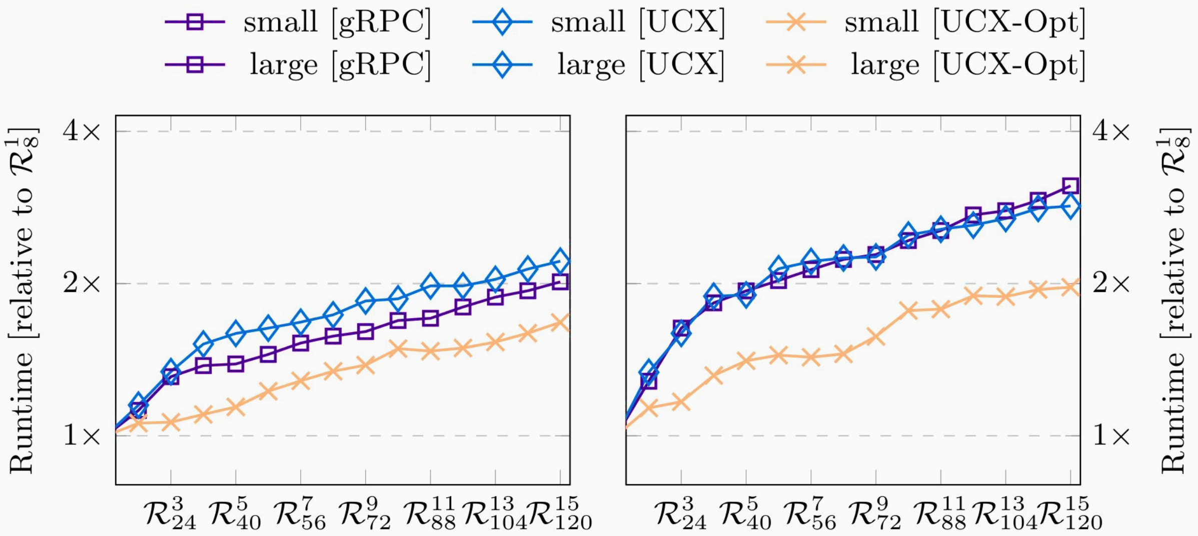

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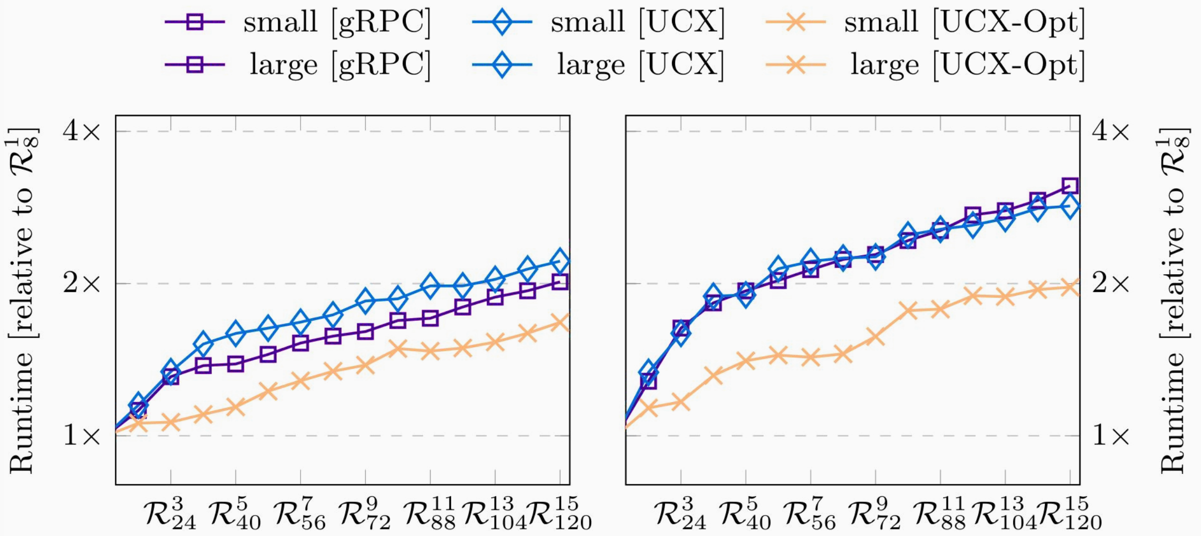

The compute to memory transfer ratio determines the effectiveness of *OpenMP Remote Offloading*.

Future Work

Multi-Device Features

```
void array(float *A, int N) {
 int numD = omp_get_num_devices();

 for (int d = 0; d < numD; ++d) {
  int chunkBegin = …, chunkSize = …, chunkEnd = …;
  #pragma omp target teams distribute           \
              parallel for default(firstprivate) \
              map(tofrom:A[chunkBegin:chunkSize])\
              device(d)
  for (int i = chunkBegin; i < chunkEnd; ++i)
    A[i] = A[i] * 2;
 }
}
```

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Multi-Device Features

- missing bulk launch

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Multi-Device Features

- missing bulk launch
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OpenMP Extension Sketch

```
void array(float *A, int N) {
 int numD = omp_get_num_devices();



  #pragma omp target teams distribute           \
              parallel for default(firstprivate) \
              map(tofrom,chunked:A[:N])          \
              devices(0:numD)
  for (int i = 0; i < N; ++i)
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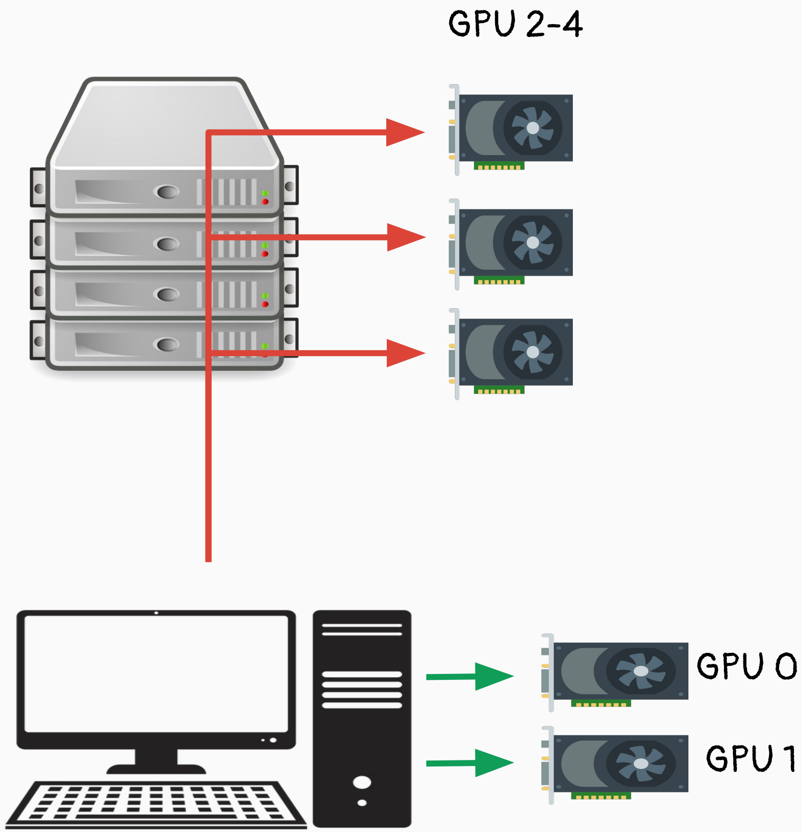

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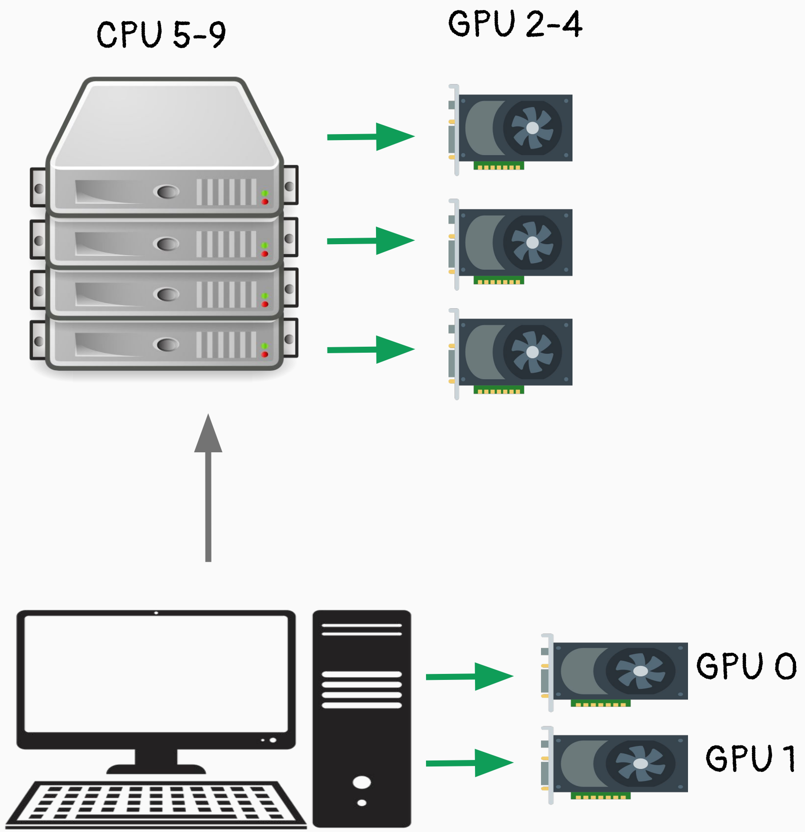

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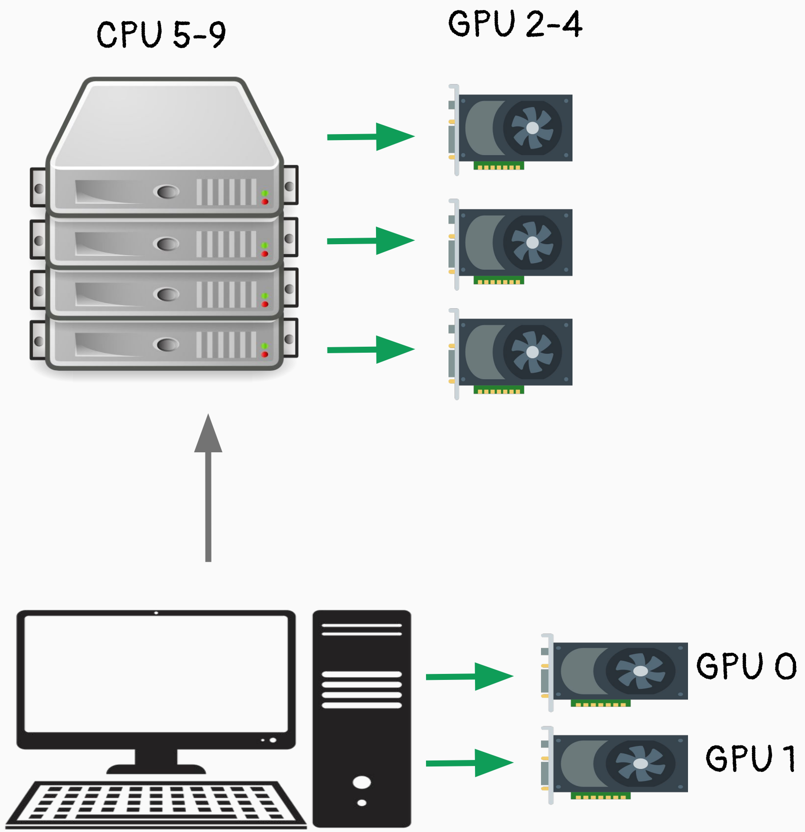

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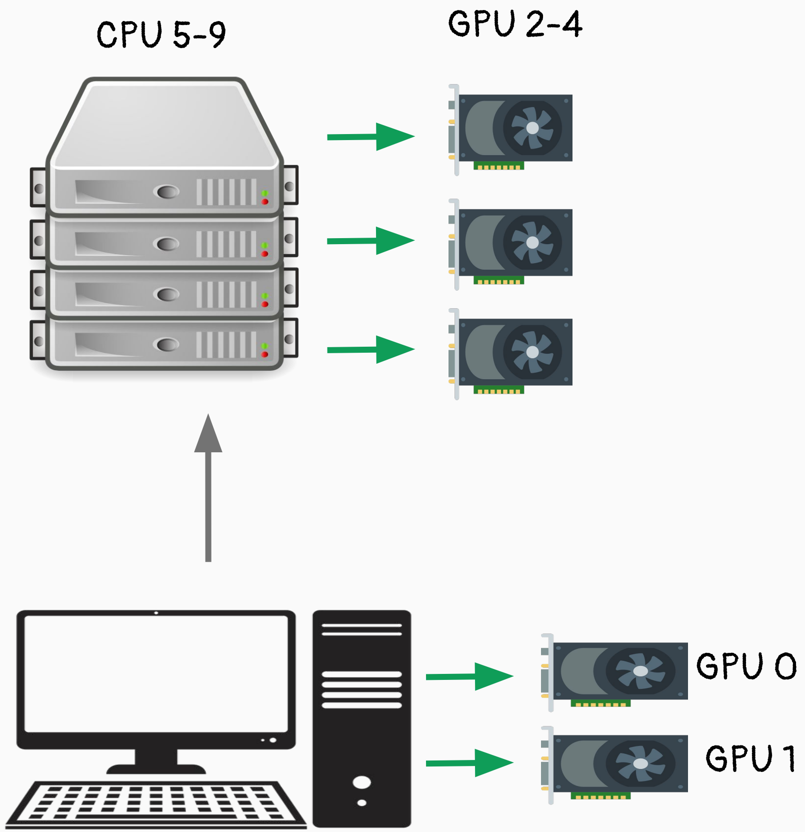

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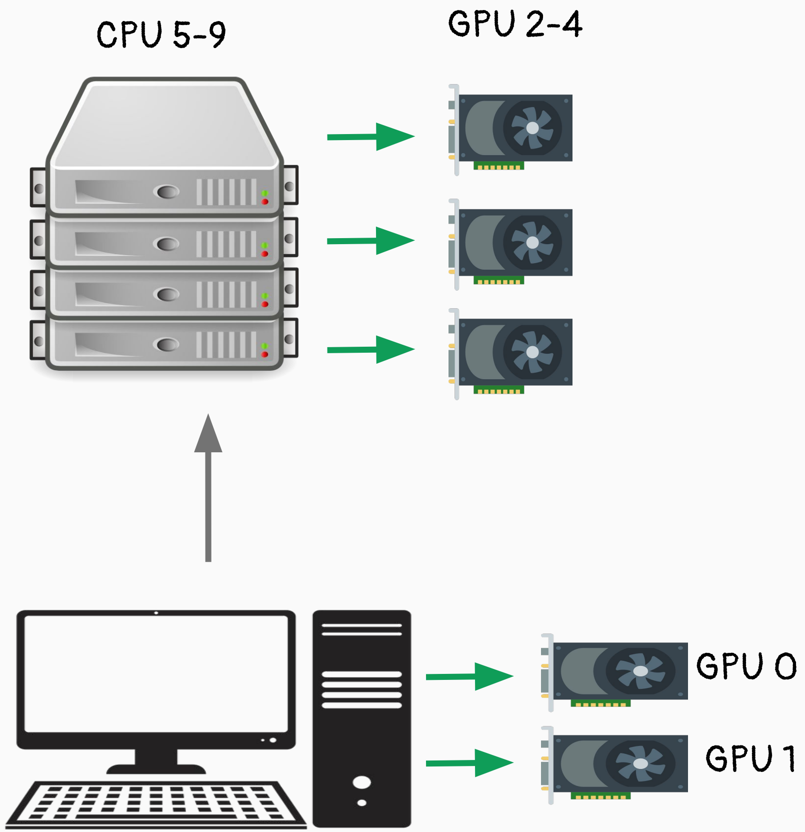

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- missing hierarchical / nested offloading
- native collective communication

Questions?