

Extreme scale AI training on LUMI

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Controlling device visibility with multiple nodes

- Rank and global rank now mean different things!
- Controlling visibility
 - HIP_VISIBLE_DEVICES=0,1,2,3 python -c 'import torch; print(torch.cuda.device_count())'
 - ROCR_VISIBLE_DEVICES=0,1,2,3 python -c 'import torch; print(torch.cuda.device_count())'
 - SLURM sets ROCR_VISIBLE_DEVICES
 - Implications of both ways of setting visibility blit kernels and/or DMA
 - Considerations:
 - Does my app expects GPU visibility to be set in the environment?
 - Does my app expects arguments to define target GPUs
 - Does my app make any assumption on the device based on other information:
 - MPI rank
 - CPU-range
 - Auto-determined
 - How many processes using the same GPU:
 - Contention vs occupancy
 - Runtime scheduling limits
 - Increased scheduling complexity
 - Imbalance

Most Pytorch applications and driver scripts assume the GPU to be used corresponds to the local rank!!!

[Public]

ORNL topology - https://docs.olcf.ornl.gov/systems/crusher_quick_start_guide.html



Testing affinity on multiple nodes

Check what SLURM is giving us:

srun -c 7 -N 2 -n 16 --gpus 16 \
bash -c 'echo "\$SLURM_PROCID -- GPUS \$ROCR_VISIBLE_DEVICES -- \$(taskset -p \$\$)"' \
| sort -n -k1

0 -- GPUS 0,1,2,3,4,5,6,7 -- pid 54249's current affinity mask: fe 1 -- GPUS 0,1,2,3,4,5,6,7 -- pid 54250's current affinity mask: fe00 2 -- GPUS 0,1,2,3,4,5,6,7 -- pid 54251's current affinity mask: fe0000 3 -- GPUS 0,1,2,3,4,5,6,7 -- pid 54252's current affinity mask: fe000000 4 -- GPUS 0,1,2,3,4,5,6,7 -- pid 54253's current affinity mask: fe00000000 5 -- GPUS 0,1,2,3,4,5,6,7 -- pid 54254's current affinity mask: fe0000000000 6 -- GPUS 0,1,2,3,4,5,6,7 -- pid 54255's current affinity mask: fe000000000000 7 -- GPUS 0,1,2,3,4,5,6,7 -- pid 54256's current affinity mask: fe000000000000000 8 -- GPUS 0,1,2,3,4,5,6,7 -- pid 110083's current affinity mask: fe 9 -- GPUS 0,1,2,3,4,5,6,7 -- pid 110084's current affinity mask: fe00 10 -- GPUS 0,1,2,3,4,5,6,7 -- pid 110085's current affinity mask: fe0000 11 -- GPUS 0,1,2,3,4,5,6,7 -- pid 110086's current affinity mask: fe000000 12 -- GPUS 0,1,2,3,4,5,6,7 -- pid 110087's current affinity mask: fe00000000 13 -- GPUS 0,1,2,3,4,5,6,7 -- pid 110088's current affinity mask: fe0000000000 14 -- GPUS 0,1,2,3,4,5,6,7 -- pid 110089's current affinity mask: fe000000000000 15 -- GPUS 0,1,2,3,4,5,6,7 -- pid 110090's current affinity mask: fe000000000000000

Careful! Allocations do not follow GPU ranking!!



Testing affinity on multiple nodes

• Check what SLURM is giving us:

Interpreted across nodes using a round-robin approach

srun -N 2 -n 16 --gpus 16 \

| sort -n -k1

0 GPUS 0,1,2,3,4,5,6,7 pid 13819's current affinity mask: fe000000000	000
1 GPUS 0,1,2,3,4,5,6,7 pid 13820's current affinity mask: fe000000000	00000
2 GPUS 0,1,2,3,4,5,6,7 pid 13821's current affinity mask: fe0000	
3 GPUS 0,1,2,3,4,5,6,7 pid 13822's current affinity mask: fe000000	
4 GPUS 0,1,2,3,4,5,6,7 pid 13823's current affinity mask: fe	
5 GPUS 0,1,2,3,4,5,6,7 pid 13824's current affinity mask: fe00	
6 GPUS 0,1,2,3,4,5,6,7 pid 13825's current affinity mask: fe00000000	
7 GPUS 0,1,2,3,4,5,6,7 pid 13826's current affinity mask: fe000000000	0
8 GPUS 0,1,2,3,4,5,6,7 pid 94670's current affinity mask: fe000000000	000
9 GPUS 0,1,2,3,4,5,6,7 pid 94671's current affinity mask: fe000000000	00000
10 GPUS 0,1,2,3,4,5,6,7 pid 94672's current affinity mask: fe0000	
11 GPUS 0,1,2,3,4,5,6,7 pid 94673's current affinity mask: fe000000	
12 GPUS 0,1,2,3,4,5,6,7 pid 94674's current affinity mask: fe	
13 GPUS 0,1,2,3,4,5,6,7 pid 94675's current affinity mask: fe00	
14 GPUS 0,1,2,3,4,5,6,7 pid 94676's current affinity mask: fe00000000	
15 GPUS 0,1,2,3,4,5,6,7 pid 94677's current affinity mask: fe00000000	00



Consider add an affinity check in your job scripts!

ORNL topology - https://docs.olcf.ornl.gov/systems/crusher_quick_start_guide.html



[Public]

Comms are important!

- ▲ LUMI, Frontier (and others) directly attaches AMD Instinct[™] MI250x Accelerator to the Slingshot Network
 - Minimize the role of the CPU in the control path
 - Lowest latency for network message passing is from GPU HBM memory

To Slingshot Network

- ▲ For example,
 - hipMalloc(&device_buffer, Msize);
 - init_data<< >>(device_buffer, Msize); // launch GPU kernel
 - hipDeviceSynchronize();
 - MPI_Sendrecv(&device_buffer, Msize, MPI_FLOAT, ... , MPI_COMM_WORLD, MPI_STATUS_IGNORE);

▲ Requires: HPE Cray MPICH

Comms are important! - RCCL AWS-CXI plugin

- LUMI, Frontier (and others) directly attaches AMD Instinct[™] MI250x Accelerator to the Slingshot Network
 - Enable collectives computation on devices
 - Minimize the role of the CPU in the control path expose more asynchronous computation opportunities
 - Lowest latency for network message passing is from GPU HBM memory



- CXI plugin is a runtime dependency. Requires: HPE Cray libfabric implementation
 - https://github.com/ROCm/aws-ofi-rccl
 - 3-4x faster collectives
- Included in the LUMI provided containers! If not using the LUMI containers make sure you have that in your environment:

export NCCL_DEBUG=INFO

export NCCL_DEBUG_SUBSYS=INIT

- # and search the logs for:
- [0] NCCL INFO NET/OFI Using aws-ofi-rccl 1.4.0

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Configuring RCCL environment

- RCCL should be set to use only high-speed-interfaces Slingshot
- The problem one might see on startup:

```
NCCL error in: /workdir/pytorch-
example/pytorch/torch/csrc/distributed/c10d/ProcessGroupNCCL.cpp:1269, unhandled
system error, NCCL version 2.12.12
```

• Check error origin by setting RCCL specific debug environment variables:

export NCCL DEBUG=INFO

Node has interfaces other than Slingshot

These are the correct ones.

NCCL INFO NET/Socket : Using [0]nmn0:10.120.116.65<0> [1]hsn0:10.253.6.67<0> [2]hsn1:10.253.6.68<0> [3]hsn2:10.253.2.12<0> [4]hsn3:10.253.2.11<0> NCCL INFO /long_pathname_so_that_rpms_can_package_the_debug_info/data/driver/rccl/src/init.cc:1292

The fix: export NCCL SOCKET IFNAME=hsn0,hsn1,hsn2,hsn3

Point RCCL to use all 4 high-speed interfaces. It will know how to bind them based on the node topology.



Configuring RCCL environment (cont.)

- RCCL should be set configured to use GPU RDMA:
 export NCCL_NET_GDR_LEVEL=PHB
- On ROCm versions (6.2) this is not needed it is default.
- Why should I spend time with all this?
 - 3-4x better bandwidth utilization with plugin
 - 2x better bandwidth utilization with RDMA
 - Can scale further!
- Careful using external containers! You may need to be setting plugin yourself!





MIOpen configuration

- MIOpen is a library for high-optimized machine learning primitives
- Used on many models not in our LLM example though
- It uses caches to enable just-in-time compilation organized as SQLite databases
- File system doesn't deal well with SQLite locks when many processes are trying to access it.
- Solution? Setup individual caches for groups of ranks we recommend per node:

export MIOPEN_USER_DB_PATH="/tmp/\$(whoami)-miopen-cache-\$SLURM_NODEID" export MIOPEN_CUSTOM_CACHE_DIR=\$MIOPEN_USER_DB_PATH

 Want to check MIOpen activity – setup the following environment variable: export MIOPEN_ENABLE_LOGGING=1

Where's the master???

Ranks need to know where the master ranks is:

export MASTER_ADDR=\$(hostname) export MASTER_PORT=29500

- When using multiple nodes this is not good enough.
- We can leverage SLURM tools to query what the first node of an allocation is:

export MASTER_ADDR=\$(scontrol show hostname "\$SLURM_NODELIST" | head -n1) export MASTER_PORT=29500

• There is no SLURM tools inside the containers:

srun singularity exec mycontainer.sif \

bash -c 'MASTER_ADDR=\$(scontrol show hostname "\$SLCRM_NODELIST" | head -n1) ./myapp'

MASTER_ADDR=\$(scontrol show hostname "\$SLURM_NODELIST" | head -n1) srun singularity exec mycontainer.sif \ bash -c './myapp'

Putting it all together



Monitoring activity with multiple nodes

- rocm-smi can still be used to understand GPU activity.
- Using SLURM to access nodes other than the first one in the allocation is possible with -w.

srun -N 1 -n 1 \ --pty \ --jobid <jobid> \ -w <target_node> \ --overlap \ /usr/bin/bash

Access the driver information:

watch –n1 rocm-smi

			==== ROC	m System	Manag	ement Ir	nterface			+ + + + +
				===== Co	ncise	Info ==				
GPU	Temp	AvgPwr	SCLK	MCLK	Fan	Perf	PwrCap	VRAM%	GPU%	
0	46.0c	92.OW	800Mhz	1600Mhz	0 %	manual	500.0W	0 %	0%	
1	52.0c	N/A	800Mhz	1600Mhz	0 %	manual	0.0W	0 %	0%	

Monitoring activity with multiple nodes - profiling

- Profiling and logging can and (most of the time) should be target at specific ranks.
 - Overhead
 - Cluttered information
- Leverage the SLURM environment to tailor the application instantiation to activate profile or logging.
 pcmd="
 if [\$SLURM_PROCID -eq 2] then

```
pcmd='rocprof --hip-trace --stats'
fi
$pcmd ./myapp
```

- If profiling with more than one rank makes sure to define rank-specific output files to avoid corruption.
 rocprof --hip-trace --stats -o myprofile-\$SLURM_PROCID.csv ./myapp
- Expect changes in the tooling names when moving to more recent ROCm releases.

Monitoring is your friend

- Why would I want to scale my model?
 - Train faster strong-scaling
 - Train bigger weak-scaling
 - My model doesn't fit in just a few GPUs
- How far can I go?
 - Depends on your model
 - Scaling can change the bottlenecks
 - Scaling can change convergence
- Monitor the regime in which your operating the GPUs at all times!



You'll always be bound by some type of communication at some point!!!

Other ways to express parallelism - FSDP

- We talked mostly about Distribute Data Parallel (DDP) applications there are others!
- Fully Sharded Data Parallel is another option.
 - Create shards out of the neural net model more likely to be activated together
 - Try keep less state in the GPU could support larger models with less GPUs
 - More complexities in configuring the different knobs. Depending on the tunning may require more or less changes to your code.
 - <u>https://pytorch.org/blog/introducing-pytorch-fully-sharded-data-parallel-api/</u>
- Using FSDP requires wrapping your model into the relevant FSDP object.

- Some tools to control the wrapping in less intrusive ways have been created accelerate.
 - Enabling FSDP on transformers: <u>https://huggingface.co/docs/transformers</u>

[Public]

Other ways to express parallelism - Horovod

 Horovod is a framework to enable distributed deep-learning training with TensorFlow, Keras, PyTorch, and Apache MXNet. The goal of Horovod is to make distributed deep learning fast and easy to use.

Configure for ROCm

export HOROVOD_WITHOUT_MXNET=1 export HOROVOD_WITHOUT_GLOO=1 export HOROVOD_GPU=ROCM export HOROVOD_ROCM_HOME=\$ROCM_PATH export HOROVOD_GPU_OPERATIONS=NCCL export HOROVOD_CPU_OPERATIONS=MPI export HOROVOD_WITH_MPI=1 export HOROVOD_ROCM_PATH=\$ROCM_PATH export HOROVOD_RCCL_HOME=\$ROCM_PATH/rccl export RCCL_INCLUDE_DIRS=\$ROCM_PATH/rccl/include export HOROVOD_RCCL_LIB=\$ROCM_PATH/rccl/lib export HOROVOD_RCCL_LIB=\$ROCM_PATH/rccl/lib export HOROVOD_RCCL_LIB=\$ROCM_PATH/rccl/lib export HCC_AMDGPU_TARGET=gfx90a export CMAKE_PREFIX_PATH=\$MPICH_PATH Step 1: configure ROCm details

Horovod needs MPI at launch

Step 2: configure for your favorite framework details

Configure for TensorFlow export HOROVOD_WITH_TENSORFLOW=1 export HOROVOD_WITHOUT_PYTORCH=1

Configure for PyTorch export HOROVOD_WITHOUT_TENSORFLOW=1 export HOROVOD_WITH_PYTORCH=1

Step 3: install



AMD together we advance_

Install

pip install --no-cache-dir --force-reinstall --verbose horovod==\$HOROVOD_VERSION

Other ways to express parallelism - DeepSpeed

• DeepSpeed is a framework to optimize distributed deep-learning training and inference



ds_report

Utility to report supported capabilities.

stochastic transformer . [YES] [OKAY]

deepspeed



Other ways to express parallelism - DeepSpeed



• Again wrapping your model in the relevant object is the way to go!

import deepspeed	
deepspeed.init_distributed()	
<pre>model, optimizer, _, _ = deepspeed.initialize(model = model, optimizer = optimizer, #e.g. SGD args = args, dist_init_required=True</pre>	Original model Original optimizer



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