Tools in action – an example with Pytorch

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LUMI Training Course
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Agenda

1. Intro to Pytorch and its dependencies
2. Controlling affinity
3. Profiling – rocprof and omnitools.
4. Debugging

Pytorch highlight

- Official page: https://pytorch.org/
- Code: https://github.com/pytorch/pytorch
- Python™-based framework for machine learning
  - Auto-differentiation on tensor types
- GPU-enabled
  - ROCm support for MI250x (and others)
  - Hipification as part of the build system
    - C/C++ libraries with proper bindings for Python
  - Python code doesn't need changing – using the same CUDA conventions
- Other related packages:
  - Torch vision/audio, many others
  - APEX – multiprecision library
    - https://github.com/ROCmSoftwarePlatform/apex

Pytorch install – base environment

```
module purge
module load CrayEnv
module load PrgEnv-cray/8.3.3
module load craype-accel-amd-gfx90a
module load cray-python

# Default ROCm – more recent versions known to work (e.g. ROCm 5.5.0)
module load rocm/5.2.3.lua
```

Pytorch install – system python

- Natively
  - cray-python module
  - pip3 install -t $(pwd)/pip-installs2 --pre torch==1.13.1 --extra-index-url https://download.pytorch.org/whl/rocm5.2/
  - PYTHONPATH=$(pwd)/pip-installs2 python -c 'import torch; print(torch.cuda.device_count())'

Pytorch install – virtual env

- virtual env
  - cray-python module
  - python -m venv --system-site-packages cray-python-virtualenv
  - source cray-python-virtualenv/bin/activate
  - pip3 install --pre torch==1.13.1 --extra-index-url https://download.pytorch.org/whl/rocm5.2/
  - python -c 'import torch; print(torch.cuda.device_count())'

Pytorch install – conda env

- conda env
  - https://repo.anaconda.com/miniconda/Miniconda3-latest-Linux-x86_64.sh
  - bash Miniconda3-latest-Linux-x86_64.sh
  - source miniconda3/bin/activate
  - conda create -n pytorch python=3.8
  - conda activate pytorch
  - conda install --only-deps pytorch
  - pip3 install --pre torch==1.13.1 --extra-index-url https://download.pytorch.org/whl/rocm5.2/
  - python -c 'import torch; print(torch.cuda.device_count())'

Pytorch install – conda env – from source

- conda env
  - https://repo.anaconda.com/miniconda/Miniconda3-latest-Linux-x86_64.sh
  - bash Miniconda3-latest-Linux-x86_64.sh
  - source miniconda3/bin/activate
  - conda create -n pytorch-build python=3.8
  - conda activate pytorch-build
  - conda install --only-deps pytorch
  - conda install -y cmake mkl-include
  - Load source and build:

```
git clone -b v1.13.1 --recursive https://github.com/pytorch/pytorch
cd pytorch
git submodule sync
git submodule update --init --recursive --jobs 0


nice python3 tools/amd_build/build_amd.py
CMAKE_PREFIX_PATH=$CONDA_PREFIX:$CMAKE_PREFIX_PATH \
  PYTORCH_ROCM_ARCH=gfx90a \
  CMAKE_MODULE_PATH=$CMAKE_MODULE_PATH:$(pwd)/pytorch/cmake/Modules_CUDA_fix \
  LIBRARY_PATH=$CONDA_PREFIX/lib:$LIBRARY_PATH LDFLAGS="-ltinfo" \
  PYTORCH_ROCM_ARCH="gfx90a" \
  RCCL_PATH=$ROCM_PATH/rccl \
  RCCL_DIR=$ROCM_PATH/rccl/lib/cmake \
  hip_DIR=${ROCM_PATH}/hip/cmake/ \
  REL_WITH_DEB_INFO=1 \
  nice python3 setup.py bdist_wheel
```

  - conda create -n pytorch-from-source --clone pytorch-build
  - conda activate pytorch-from-source
  - pip install dist/torch-*.whl LD_LIBRARY_PATH=$CONDA_PREFIX/lib:$LD_LIBRARY_PATH python -c 'import torch; print(torch.cuda.device_count())'

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Controlling device visibility

- 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

Testing affinity

- What CPUs I have available and their NUMA domain?
  - lscpu
- What GPUs I have
  - rocm-smi –showtopo

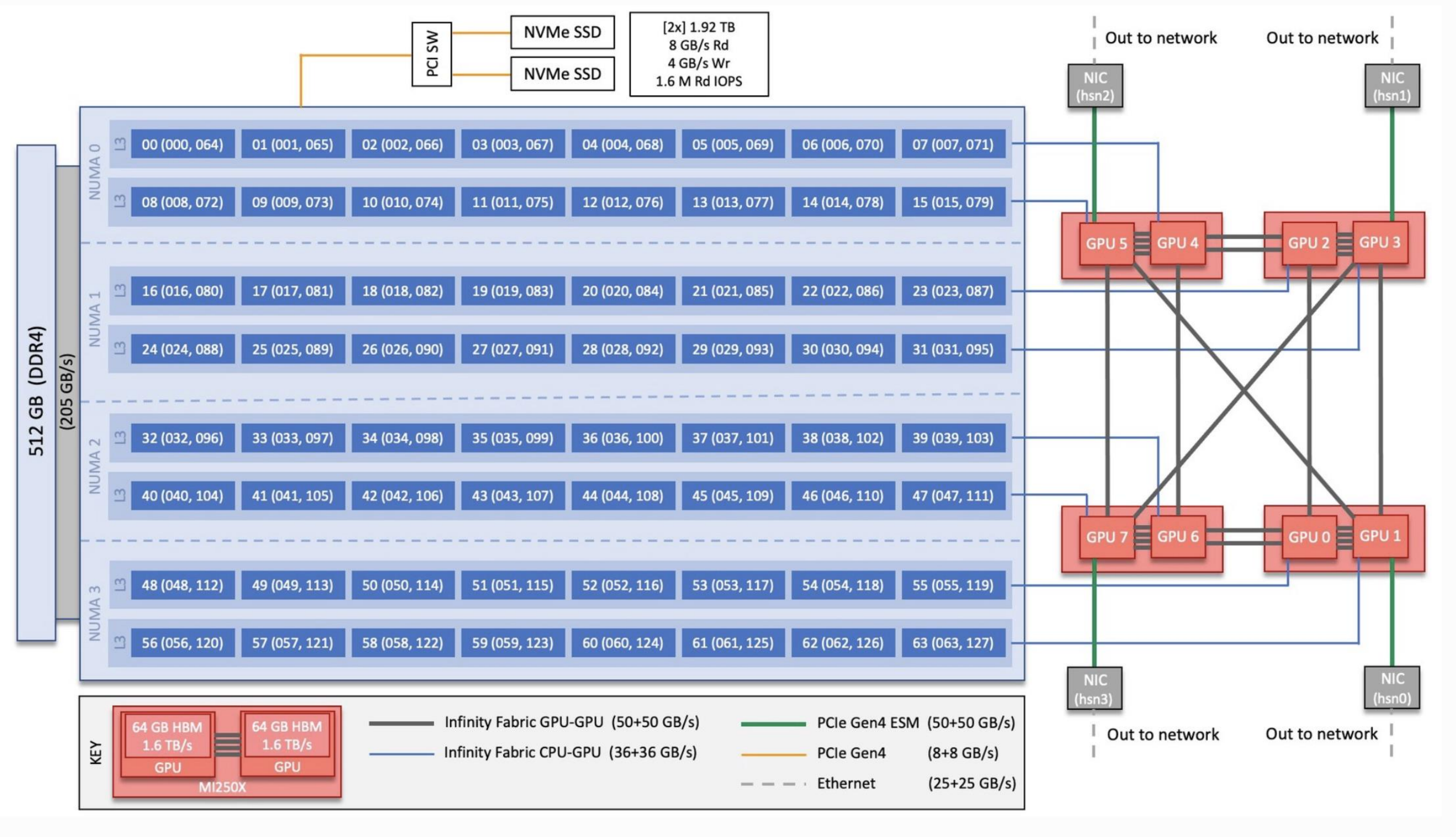
NUMA node0 CPU(s):	0-15,64-79
NUMA node1 CPU(s):	16-31,80-95
NUMA node2 CPU(s):	32-47,96-111
NUMA node3 CPU(s):	48-63,112-127

GPU[0]	: (Topology) Numa Node: 3
GPU[0]	: (Topology) Numa Affinity: 3
GPU[1]	: (Topology) Numa Node: 3
GPU[1]	: (Topology) Numa Affinity: 3
GPU[2]	: (Topology) Numa Node: 1
GPU[2]	: (Topology) Numa Affinity: 1
GPU[3]	: (Topology) Numa Node: 1
GPU[3]	: (Topology) Numa Affinity: 1
GPU[4]	: (Topology) Numa Node: 0
GPU[4]	: (Topology) Numa Affinity: 0
GPU[5]	: (Topology) Numa Node: 0
GPU[5]	: (Topology) Numa Affinity: 0
GPU[6]	: (Topology) Numa Node: 2
GPU[6]	: (Topology) Numa Affinity: 2
GPU[7]	: (Topology) Numa Node: 2
GPU[7]	: (Topology) Numa Affinity: 2

[Public]

Testing affinity

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



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Testing affinity

- Check what SLURM is giving us:
  - `N=2 ;  salloc -p small-g --threads-per-core 1 --exclusive -N $N --gpus $((N*8)) -t 2:00:00  --account project_465000524 --mem 0`
  - `srun -c 7 -N 2 -n 16 --gpus 16 bash -c 'echo "$SLURM_PROCID -- GPUS $ROCR_VISIBLE_DEVICES -- $(taskset -p $$)"'`

```
 0 -- GPUs 0,1,2,3,4,5,6,7 -- pid 29793's current affinity mask: fe
 1 -- GPUs 0,1,2,3,4,5,6,7 -- pid 29794's current affinity mask: 7f00
 2 -- GPUs 0,1,2,3,4,5,6,7 -- pid 29795's current affinity mask: 3f8000
 3 -- GPUs 0,1,2,3,4,5,6,7 -- pid 29796's current affinity mask: 1fc00000
 4 -- GPUs 0,1,2,3,4,5,6,7 -- pid 29797's current affinity mask: fe0000000
 5 -- GPUs 0,1,2,3,4,5,6,7 -- pid 29798's current affinity mask: 7f000000000
 6 -- GPUs 0,1,2,3,4,5,6,7 -- pid 29799's current affinity mask: 3f80000000000
 7 -- GPUs 0,1,2,3,4,5,6,7 -- pid 29800's current affinity mask: 1fc000000000000
 8 -- GPUs 0,1,2,3,4,5,6,7 -- pid 35973's current affinity mask: fe
 9 -- GPUs 0,1,2,3,4,5,6,7 -- pid 35974's current affinity mask: 7f00
10 -- GPUs 0,1,2,3,4,5,6,7 -- pid 35975's current affinity mask: 3f8000
11 -- GPUs 0,1,2,3,4,5,6,7 -- pid 35976's current affinity mask: 1fc00000
12 -- GPUs 0,1,2,3,4,5,6,7 -- pid 35977's current affinity mask: fe0000000
13 -- GPUs 0,1,2,3,4,5,6,7 -- pid 35978's current affinity mask: 7f000000000
14 -- GPUs 0,1,2,3,4,5,6,7 -- pid 35979's current affinity mask: 3f80000000000
15 -- GPUs 0,1,2,3,4,5,6,7 -- pid 35980's current affinity mask: 1fc000000000000
```

Not good! Allocations crossing NUMA domains!!

RCCL attempt using only high-speed-interfaces

- The problem – on startup we see:
  NCCL error in: /pfs/lustrep2/projappl/project_462000125/samantao/pytorch-example/pytorch/torch/csrc/distributed/c10d/ProcessGroupNCCL.cpp:1269, unhandled system error, NCCL version 2.12.12

- Checking error origin:
  - export NCCL_DEBUG=INFO
  - 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

Pytorch example app – transformer – training MLPerf

- Translation benchmark
  - Bind script
    - N=1 ; salloc -p small-g --threads-per-core 1 --exclusive -N $N --gpus $((N*8)) -t 0:10:00 --account project_465000524 --mem 0
    - run_training_lumi.sh
    - bind_launch.py
  - Explicit numactl within SLURM environment
    - Leveraging numactl library within launching script
    - Set bind to none to have all resources available for each spawn process
  - SLURM launch
    - Use binding masks to control bind
    - Recreate Pytorch distributed environment from SLURM environment
    - Watch out for SLURM inconsistencies.

Pytorch example app - profiling

- Rocprof
  - Hip trace

- Reduce profiling scope and load large profiles
  - Break epoch loops
  - Break iteration loops
  - trace_processor for large profiles

RCCL AWS-CXI plugin

- RCCL relies on runtime plugin-ins to connect with some transport layers
  - Libfabric – provider for Slingshot

- Hipified plugin adapted from AWS OpenFabrics support available
- https://github.com/ROCmSoftwarePlatform/aws-ofi-rccl
- 3-4x faster collectives

- Plugin needs to be pointed at by the loading environment

```
module use /pfs/lustrep2/projappl/project_462000125/samantao-public/mymodules
module load aws-ofi-rccl/rocm-5.2.3.lua
Or
export LD_LIBRARY_PATH=/pfs/lustrep2/projappl/project_462000125/samantao-public/apps-rocm-5.2.3/aws-ofi-rccl
(will detect librccl-net.so)
```

- Verify the plugin is detected.

```
 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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Omnitrace

- Obtain more thorough trace information and visualization
  - https://github.com/AMDResearch/omnitrace
  - OpenSUSE 15.3 build mainly compatible with LUMI environment

- Module files to help assist, e.g.
  - module use /pfs/lustref1/flash/project_462000125/samantao/lumi-training/omnitools/omnitrace-1.10.0-opensuse-15.3-ROCm-50200-PAPI-OMPT-Python3/share/modulefiles
  - module load omnitrace

- Configuration file:
  - omnitrace-avail -G omnitrace.cfg –all
  - Use OMNITRACE_CONFIG_FILE environment variable to point to it
  - Override environment with command line arguments

- Sampling the Python™ and C/C++ parts of the code
  - omnitrace-python-3.8 -c <configuration path>/omnitrace.cfg – script.py"
  - omnitrace-sample --trace –c <configuration path>/omnitrace.cfg -- python –u ./scripts.py
  - Match omnitrace-python with your Python version.

Omniperf

- Obtain detail kernel performance counters
  - https://github.com/AMDResearch/omniperf
  - OpenSUSE 15.3 build mainly compatible with LUMI environment
- Module files to help assist, e.g.
  - module use /flash/project_462000125/samantao/lumi-training/omnitools/omniperf-modulefiles
  - module load omniperf
- Configuration and build:
  - Omniperf requirements must be installed in a Python version and environment compatible with the one used by the target app.
  - E.g. make sure omniperf requirements exist within same conda environment.
  - Sampling the Python and C/C++ parts of the code
- Omniperf needs replaying the application
  - Complicated to profile individual ranks as all need replaying.
- Profile with:
  - omniperf profile -n pytorch --device 0 --roof-only -- $(which python) -u
- Analyze with:
  - omniperf analyze -p workloads/pytorch/mi200/ --gui

Rocgdb

- https://github.com/ROCm-Developer-Tools/ROCgdb/
  - Branches for given ROCm releases: e.g. rocm-5.2.x
- Two main use cases
  - Connecting into a hanging process
  - Progress up to breakpoint or segfault
- ROCm provides rocgdb – you may need your own gdbserver.

- Using gdbserver
  - gdbserver can be issued conveniently as a profile tool
  - Launch with:
    - gdbserver --once $(hostname):12345 ./my_command
  - Attach with
    - rocgdb -x gdb.commands ./my_command
  - Leverage gdb commands file to automate startup
    - target remote target_host:12345

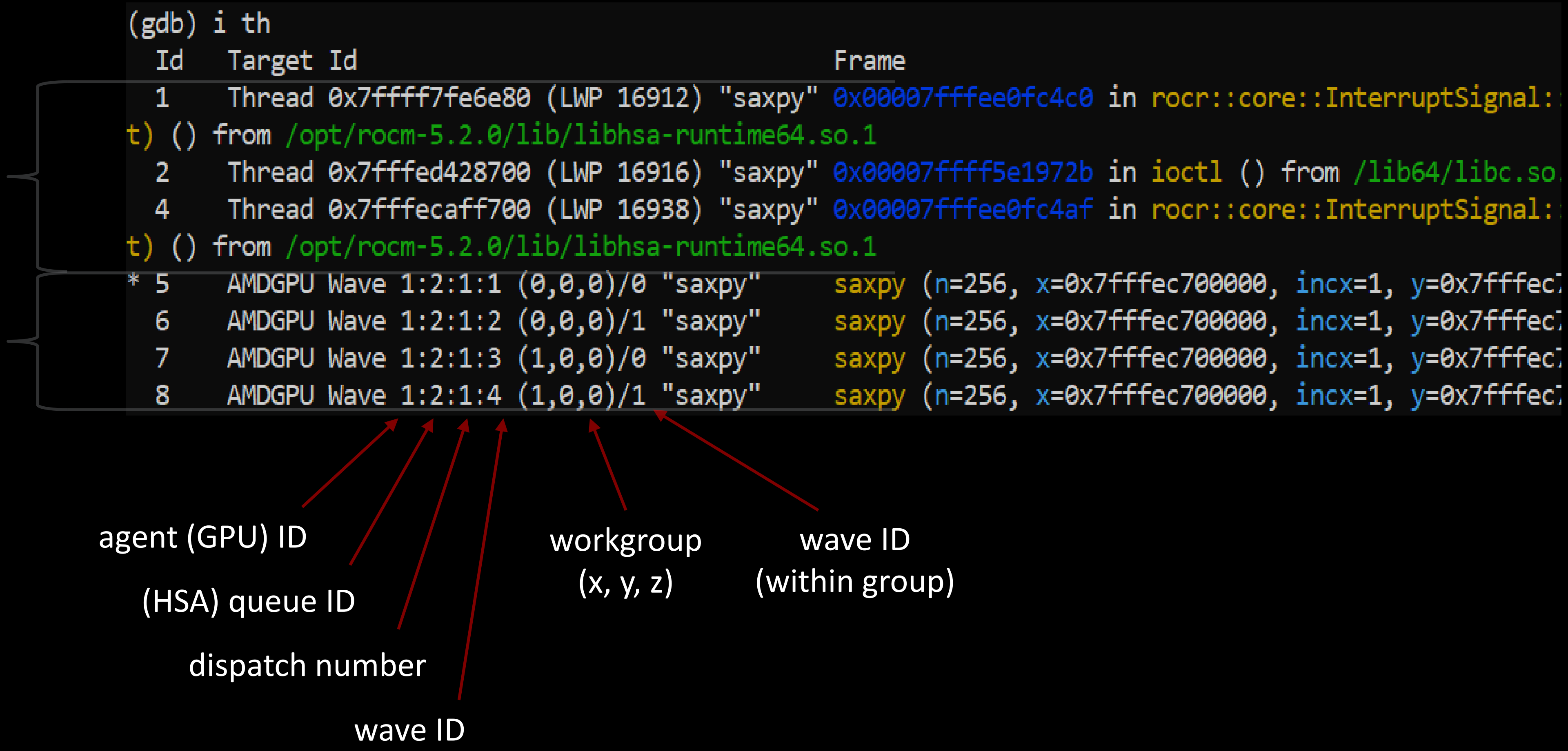
- Two examples:
  - Hanging in collective (RCCL)
  - Connect to remote gdb session – breakpoints

- Limitations
  - GPU pending breakpoints over gdbserver may not work.

- Staring session in specific to nodes
  - srun --interactive --pty /bin/bash   (only works for first node of allocation)
  - srun --pty --jobid <jobid> -w <target_node> --mem=0 --oversubscribe –interactive -n 1 -c 63 --gpus-per-task=0 /usr/bin/bash (GPU's won't be visible)

Wave details

`agent-id:queue-id:dispatch-num:wave-id (work-group-x,work-group-y,work-group-z)/work-group-thread-index`



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