NVIDIA NVSHMEM

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Installation Guide

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Chapter 1. OVERVIEW

NVIDIA® NVSHMEM™ is a programming interface that implements a Partitioned Global Address Space (PGAS) model across a cluster of NVIDIA GPUs. NVSHMEM provides an easy-to-use interface to allocate memory that is symmetrically distributed across the GPUs. In addition to a CPU-side interface, NVSHMEM also provides a CUDA kernel-side interface that allows CUDA® threads to access any location in the symmetrically-distributed memory.

Chapter 2. HARDWARE AND SOFTWARE REQUIREMENTS

NVIDIA® NVSHMEM™ has the following hardware and software requirements.

2.1. Hardware Requirements

NVSHMEM requires the following hardware:

- x86_64 CPU architecture
- NVIDIA® Tesla® GPUs, NVIDIA® Volta® GPU architecture or newer. A full list is available at the following website:

  https://developer.nvidia.com/cuda-gpus
- All GPUs must be P2P connected (directly via NVLink or PCIe) or must have GPUDirect RDMA enabled with a Mellanox InfiniBand adapter.

2.2. Software Requirements

NVSHMEM requires the following software:

- 64-bit Linux. For a complete compatibility matrix, see the NVIDIA CUDA Installation Guide for Linux.
- CUDA 10.1 or newer
- Mellanox OFED
- **`nv_peer_mem for GPUDirect RDMA`**
- GDRCopy v2.0 or newer

Chapter 3. INSTALLATION

3.1. Downloading NVSHMEM

1. Ensure you are a registered partner and have access to NVONLINE.
2. Download and extract the NVSHMEM **txz** archive. The extracted directory contains the following files and subdirectories:

File or Directory	Description
src/	Contains NVSHMEM sources and headers.
perftest/	Contains tests showing use of NVSHMEM APIs with performance reporting.
examples/	Contains examples showing use of some common use cases of NVSHMEM.
scripts/	Contains helper scripts, for example, script to download, build and install Hydra.
COPYRIGHT.txt	Copyright information.
NVSHMEM-SLA.txt	NVSHMEM service level agreement (SLA).

3.2. Building And Installing NVSHMEM

1. Set the environment variable **CUDA_HOME** to point to the CUDA Toolkit.
2. Set the environment variable **GDRCOPY_HOME** to point to the GDRCopy installation.
3. If MPI and/or SHMEM support is required, set **NVSHMEM_MPI_SUPPORT=1** and/or **NVSHMEM_SHMEM_SUPPORT=1**. Set the environment variables **MPI_HOME** and **SHMEM_HOME** to point to the MPI and OpenSHMEM installations, respectively.

4. If the MPI library is neither OpenMPI nor its derivative, set **NVSHMEM_MPI_IS_OMPI=0**.

When using OpenMPI and OSHMEM, the paths are the same. To use OSHMEM, OpenMPI needs to be built with UCX support. NVSHMEM has been tested with OpenMPI 4.0.1 and UCX 1.8.0. Other MPI and OpenSHMEM installations are expected to work. By default, MPI support is enabled and OpenSHMEM support is disabled.

5. Set **NVSHMEM_PREFIX** to specify the location where NVSHMEM will be installed.
6. Run **make -j8 install** to build and install the library.

3.3. Using NVSHMEM In Your Applications

3.3.1. Using NVSHMEM With Your C Or C++ Program

1. Include **nvshmem.h** and **nvshmemx.h** from **include/**.
2. Point to the **include/** and **lib/** paths.
3. NVSHMEM users: If your C or C++ program only uses NVSHMEM, install Hydra Process Manager using the bash script **install_hydra.sh** under the **scripts/** directory. Provide the download and install location as arguments, for example:

```
./install_hydra.sh <download_path> <install_path>
```

Use **nvshmrun** launcher under **bin/** (of the Hydra install path) to run the NVSHMEM job.

3.3.2. Using NVSHMEM With Your MPI Program

The only MPI library currently tested is OpenMPI, however, derivatives of OpenMPI such as SpectrumMPI as well as MPICH derivatives are expected to work.

To run a Hybrid MPI + NVSHMEM program, use the **mpirun** launcher available in the MPI installation.

Similarly, NVSHMEM can be used from OpenSHMEM programs, you cannot use the launchers provided in the NVSHMEM package. The only OpenSHMEM version currently tested is OSHMEM in OpenMPI. Other OpenSHMEM implementations such as Sandia OpenSHMEM (SOS) are expected to work. Use the **oshrun** launcher available in the OpenMPI installation (or follow the launcher specification of your OpenSHMEM library) to run the hybrid OpenSHMEM/NVSHMEM job.

3.4. Running Performance Tests

Before you can run performance tests, you first must build them.

1. Set the **CUDA_HOME**, **NVSHMEM_HOME** and **MPI_HOME** (if the NVSHMEM library was built with **NVSHMEM_MPI_SUPPORT=1**) environment variables to build NVSHMEM performance tests:

   ```
   CUDA_HOME=<path to supported CUDA installation>
   NVSHMEM_HOME=<path to directory where NVSHMEM is installed>
   MPI_HOME=<path to MPI installation>
   ```

   Configuring OpenMPI using the **-with-ucx** option is required for OpenMPI/OSHMEM interoperability. If you have built NVSHMEM with MPI and OpenSHMEM support (**NVSHMEM_MPI_SUPPORT=1** and **NVSHMEM_SHMEM_SUPPORT=1**), building **perftest/** also requires MPI and OpenSHMEM support to be enabled.

   Build without SHMEM interoperability: To build NVSHMEM performance tests without SHMEM interoperability, set the environment variable **NVSHMEM_SHMEM_SUPPORT** to **0**. By default, performance tests are installed under **perftest/perftest_install**. To install to a different path, set **PERFTEST_INSTALL** to point to the desired path.
2. Update **LD_LIBRARY_PATH** to point to **$CUDA_HOME/lib64** and **$MPI_HOME/lib**.
3. Run performance tests as NVSHMEM jobs (assuming Hydra is installed under **HYDRA_HOME**), hybrid MPI+NVSHMEM jobs, or hybrid OpenSHMEM+NVSHMEM jobs with the following commands (using **perftest/device/pt-to-pt/put.cu** as an example):

   NVSHMEM job:

   ```
   $HYDRA_HOME/bin/nvshmrun -n <up to number of P2P or InfiniBand NIC
    accessible GPUs> $PERFTEST_INSTALL/device/pt-to-pt/shmem_put_bw
   ```

   Hybrid MPI/NVSHMEM job:

   ```
   $MPI_HOME/bin/mpirun -n <up to number of GPUs accessible by P2P or
    InfiniBand NIC> -x NVSHMEMTEST_USE_MPI_LAUNCHER=1 $PERFTEST_INSTALL/device/
   pt-to-pt/shmem_put_bw
   ```

   Hybrid OpenSHMEM/NVSHMEM job:

   ```
   $MPI_HOME/bin/oshrun -n <up to number of GPUs accessible by P2P or
    InfiniBand NIC> -x USE_SHMEM_IN_TEST=1 $PERFTEST_INSTALL/device/pt-to-pt/
   shmem_put_bw
   ```

3.5. "Hello World" Example

1. Save the following code as **nvshmemHelloWorld.cu**:

   ```
   #include <stdio.h>
   #include <cuda.h>
   ```

```
#include <nvshmem.h>
#include <nvshmemx.h>

__global__ void simple_shift(int *destination) {
    int mype = nvshmem_my_pe();
    int npes = nvshmem_n_pes();
    int peer = (mype + 1) % npes;

    nvshmem_int_p(destination, mype, peer);
}

int main(void) {
    int mype_node, msg;
    cudaStream_t stream;

    nvshmem_init();
    mype_node = nvshmem_team_my_pe(NVSHMEMX_TEAM_NODE);
    cudaSetDevice(mype_node);
    cudaStreamCreate(&stream);

    int *destination = (int *) nvshmem_malloc(sizeof(int));

    simple_shift<<<1, 1, 0, stream>>>(destination);
    nvshmemx_barrier_all_on_stream(stream);
    cudaMemcpyAsync(&msg, destination, sizeof(int), cudaMemcpyDeviceToHost,
 stream);

    cudaStreamSynchronize(stream);
    printf("%d: received message %d\n", nvshmem_my_pe(), msg);

    nvshmem_free(destination);
    nvshmem_finalize();
    return 0;
}
```

2. Build **nvshmemHelloWorld.cu** with the following command:

```
nvcc -rdc=true -ccbin g++ -gencode=$NVCC_GENCODE -I $NVSHMEM_HOME/include
 nvshmemHelloWorld.cu -o nvshmemHelloWorld.out -L $NVSHMEM_HOME/lib -
lnvshmem
-lcuda
```

Where **arch=compute_70, code=sm_70** is the value of **NVCC_GENCODE** for V100 GPUs.

3. Run the **nvshmemHelloWorld** sample with one of the following commands:

When running on a single host with 2 GPUs (connected by PCI-E, NVLink or Infiniband):

```
$HYDRA_HOME/bin/nvshmrun -n 2 -ppn 2 ./nvshmemHelloWorld.out
```

When running on two hosts with 1 GPU per host (connected by InfiniBand):

```
$HYDRA_HOME/bin/nvshmrun -n 2 -ppn 1 --hosts hostname1,hostname2 ./
nvshmemHelloWorld.out
```

Chapter 4. SUPPORT

Report bugs and submit feature requests using NVONLINE or by emailing nvshmem@nvidia.com.

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