NVIDIA COLLECTIVE COMMUNICATION LIBRARY (NCCL)

RN-08645-000_v2.5.6 | November 2019

Release Notes
TABLE OF CONTENTS

Chapter 1. NCCL Overview.................................................................1
Chapter 2. NCCL Release 2.5.6..............................................................3
Chapter 3. NCCL Release 2.4.8..............................................................4
Chapter 4. NCCL Release 2.4.7..............................................................6
Chapter 5. NCCL Release 2.4.2..............................................................8
Chapter 6. NCCL Release 2.3.7..............................................................9
Chapter 7. NCCL Release 2.3.5.............................................................10
Chapter 8. NCCL Release 2.3.4.............................................................11
Chapter 9. NCCL Release 2.2.13..........................................................12
Chapter 10. NCCL Release 2.2.12.........................................................14
Chapter 11. NCCL Release 2.1.15..........................................................16
Chapter 12. NCCL Release 2.1.4..........................................................18
Chapter 13. NCCL Release 2.1.2..........................................................20
Chapter 14. NCCL Release 2.0.5..........................................................21
Chapter 15. NCCL Release 2.0.4..........................................................23
Chapter 16. NCCL Release 2.0.2..........................................................25
Chapter 1.
NCCL OVERVIEW

The NVIDIA® Collective Communications Library™ (NCCL) (pronounced “Nickel”) is a library of multi-GPU collective communication primitives that are topology-aware and can be easily integrated into applications.

Collective communication algorithms employ many processors working in concert to aggregate data. NCCL is not a full-blown parallel programming framework; rather, it is a library focused on accelerating collective communication primitives. The following collective operations are currently supported:

- AllReduce
- Broadcast
- Reduce
- AllGather
- ReduceScatter

Tight synchronization between communicating processors is a key aspect of collective communication. CUDA® based collectives would traditionally be realized through a combination of CUDA memory copy operations and CUDA kernels for local reductions. NCCL, on the other hand, implements each collective in a single kernel handling both communication and computation operations. This allows for fast synchronization and minimizes the resources needed to reach peak bandwidth.

NCCL conveniently removes the need for developers to optimize their applications for specific machines. NCCL provides fast collectives over multiple GPUs both within and across nodes. It supports a variety of interconnect technologies including PCIe, NVLink™, InfiniBand Verbs, and IP sockets. NCCL also automatically patterns its communication strategy to match the system’s underlying GPU interconnect topology.

Next to performance, ease of programming was the primary consideration in the design of NCCL. NCCL uses a simple C API, which can be easily accessed from a variety of programming languages. NCCL closely follows the popular collectives API defined by MPI (Message Passing Interface). Anyone familiar with MPI will thus find NCCL API very natural to use. In a minor departure from MPI, NCCL collectives take a “stream” argument which provides direct integration with the CUDA programming model. Finally, NCCL is compatible with virtually any multi-GPU parallelization model, for example:
NCCL has found great application in deep learning frameworks, where the **AllReduce** collective is heavily used for neural network training. Efficient scaling of neural network training is possible with the multi-GPU and multi node communication provided by NCCL.
This is the NCCL 2.5.6 release notes. For previous NCCL release notes, refer to the NCCL Archives.

**Key Features and Enhancements**

This NCCL release includes the following key features and enhancements.

- Added the LL128 Protocol for better performance on small operations.
- Improved topology detection and tree/ring creation (#179).
- Improved multi-node tree performance by sending/receiving from different GPUs.
- Added model-based tuning to switch between the different algorithms and protocols.
- Reworked P2P/SHM detection in containers (#155, #248).
- Added detection for duplicate CUDA devices and return an error (#231).
- Added tuning for Google Cloud’s gVNIC platform.

**Compatibility**

NCCL 2.5.6 has been tested with the following:

- Deep learning framework containers. Refer to the [Support Matrix](#) for the supported container version.
- This NCCL release supports [CUDA 9.0](#), [CUDA 10.0](#), and [CUDA 10.2](#).

**Fixed Issues**

The following issues have been resolved in NCCL 2.5.6:

- Sporadic NCCL error "ring 0 does not loop back to start" (#179).
Chapter 3.
NCCL RELEASE 2.4.8

This is the NCCL 2.4.8 release notes. This release includes fixes from the previous NCCL 2.4.x releases as well as the following additional changes. For previous NCCL release notes, see the archived NCCL Release Notes.

Key Features and Enhancements
This NCCL release includes the following key features and enhancements.

‣ Improved socket transport performance by splitting transfer over multiple sockets.

This feature adds two new environment variables `NCCL_SOCKET_NTHREADS` and `NCCL_NSOCKS_PERTHREAD` for users to tune NCCL performance on socket-based networks. See the NCCL documentation for more details.

Compatibility
NCCL 2.4.8 has been tested with the following:

‣ Deep learning framework 19.05 containers
‣ This NCCL release supports; CUDA 9.0, CUDA 9.2, CUDA 10.0, and CUDA 10.1.

Fixed Issues
The following issues have been resolved in NCCL 2.4.8:

‣ Suboptimal performance with TCP over high bandwidth networks. (GitHub issue #209)

Known Issues
‣ On single node Power systems with 4 GPUs, some performance regressions have been observed compared to NCCL 2.4.2. These will be addressed in future NCCL releases.
By default, NCCL does not enable direct P2P communication through different PCIe root ports on Intel Skylake CPU and later. This is due to a known performance issue when using P2P on these CPU versions. There is now a new BIOS and performance tuning option available (PCIe Peer-to-Peer Serialization) from Intel and their OEM vendors that resolves this P2P bandwidth issue. If the BIOS performance tuning option has been enabled, then NCCL direct P2P connections can be re-enabled by setting `NCCL_P2P_LEVEL=5`. 
Chapter 4.
NCCL RELEASE 2.4.7

This is the NCCL 2.4.7 release notes. This release includes fixes from the previous NCCL 2.4.x releases as well as the following additional changes. For previous NCCL release notes, see the archived NCCL Release Notes.

Key Features and Enhancements

This NCCL release includes the following key features and enhancements.

‣ Improved bootstrap socket connection reliability at scale.
‣ Added detection of IBM/Power NVLink bridge device.
‣ Added NUMA support to PCI-E distance calculations on x86 architectures.

This adds a new level (5) for the NCCL_P2P_LEVEL and NCCL_NET_GDR_LEVEL environment variables. See the NCCL documentation for more details.

‣ Added the NCCL_IGNORE_CPU_AFFINITY environment variable.

Compatibility

NCCL 2.4.7 has been tested with the following:

‣ Deep learning framework 19.04 containers
‣ This NCCL release supports; CUDA 9.0, CUDA 9.2, CUDA 10.0, and CUDA 10.1.

Fixed Issues

The following issues have been resolved in NCCL 2.4.7:

‣ Fixed hostname hashing issue. (GitHub issue #187)
‣ Fixed memory leaks. (GitHub issue #180)
‣ Fixed compiler warning. (GitHub issue #178)
‣ Replaced non-standard variable length arrays. (GitHub issue #171)
‣ Fixed Tree and Shared Memory crash. (GitHub PR #185)
Fixed hangs during long running jobs.

- Fixed the **NCCL_RINGS** environment variable handling.
- Added extra checks to catch duplicate calls to `ncclCommDestroy()`. (GitHub issue #191)

### Known Issues

- On single node Power systems with 4 GPUs, some performance regressions have been observed compared to NCCL 2.4.2. These will be addressed in future NCCL releases.
- By default, NCCL does not enable direct P2P communication through different PCIe root ports on Intel Skylake CPU and later. This is due to a known performance issue when using P2P on these CPU versions. There is now a new BIOS and performance tuning option available (PCIe Peer-to-Peer Serialization) from Intel and their OEM vendors that resolves this P2P bandwidth issue. If the BIOS performance tuning option has been enabled, then NCCL direct P2P connections can be re-enabled by setting `NCCL_P2P_LEVEL=5`. 
Chapter 5.
NCCL RELEASE 2.4.2

Key Features and Enhancements

This NCCL release includes the following key features and enhancements.

‣ Implemented tree-based algorithms for better All Reduce performance at scale and with small and medium size messages.
‣ Support for external network plugins (e.g., libfabric).
‣ Add ncclCommGetAsyncError() function to report errors happening during collective operations.
‣ Add ncclCommAbort() function to destroy a communicator, aborting any outstanding operations.
‣ Support different ranks having a different CUDA_VISIBLE_DEVICES.
‣ Add a best-effort mechanism to check for size mismatch among collective calls.

Fixed Issues

‣ Support communication between Mesos containers (Github issue #155).
‣ Fix case where posix_fallocate() returns EINTR (Github issue #137).
‣ NCCL threads no longer escape the CPU affinity set by the user or job scheduler.
Chapter 6.  
NCCL RELEASE 2.3.7

Key Features and Enhancements
This NCCL release includes the following key features and enhancements.

- Minor tuning of the LL threshold for multi-node jobs.
- Improve performance of initialization on large number of ranks.

Fixed Issues

- Fixed issue causing "WARN : Message truncated" errors.
Chapter 7.
NCCL RELEASE 2.3.5

Key Features and Enhancements
This NCCL release includes the following key features and enhancements.

- This release is open-sourced with no new features or fixes.
Key Features and Enhancements

This NCCL release includes the following key features and enhancements.

- Improve performance tuning on large number of ranks.
- Add `NCCL_P2P_LEVEL` and `NCCL_IB_GDR_LEVEL` knobs to finely control when to use GPU Direct P2P and GPU Direct RDMA.
- Reduce setup time for large scale jobs.
- Increased maximum number of rings supported to 16.
- Added a runtime NCCL version API: `ncclGetVersion()`.
- Added NCCL_DEBUG_SUBSYS to allow filtering of `NCCL_DEBUG=INFO` logging from different subsystems.
- Support for Turing based systems.

Fixed Issues

- Fix hang on Power platforms.
- Fix low inter-node bandwidth issue on multi-DGX2 systems.
- Fix crash when used with PID isolator.
Chapter 9.  
NCCL RELEASE 2.2.13

Key Features and Enhancements
There were no new features and enhancements in this release.

Using NCCL 2.2.13
Ensure you are familiar with the following notes when using this release.

‣ If NCCL returns an error code, set the environment variable `NCCL_DEBUG` to `WARN` to receive an explicit error message.
‣ The NCCL 2.x API is different from NCCL 1.x. Some porting may be needed for NCCL 1.x applications to work correctly. Refer to the migration documentation in the NCCL Developer Guide.
‣ Starting in 2.2, NCCL supports collective aggregation. You can put multiple NCCL collective operations in between `ncclGroupStart()` and `ncclGroupEnd()` to enable this feature.

Known Issues
‣ Using multiple processes in conjunction with multiple threads to manage the different GPUs may in some cases cause `ncclCommInitRank` to fail while establishing IPCs (`cudaIpcOpenMemHandle`). This problem does not appear when using only processes or only threads. This issue is fixed in recent driver versions, therefore, consider updating to the latest driver.
‣ NCCL uses CUDA 9 cooperative group launch by default, which may induce increased latencies in multi-threaded programs. See the `NCCL_LAUNCH_MODE` knob to restore the original behavior.
‣ Driver version 390 can cause data corruption when used together with GPU Direct RDMA. Disabling GPU Direct RDMA by setting `NCCL_IB_CUDA_SUPPORT=0`, or upgrading to 396.26 or newer driver should resolve the issue.
Fixed Issues

- Fix crash in child processes after calling `ncclCommDestroy`.
Chapter 10.
NCCL RELEASE 2.2.12

Key Features and Enhancements
This NCCL release includes the following key features and enhancements.

‣ Added support for collective operations aggregation.
‣ Added `ncclBroadcast` function.

Using NCCL 2.2.12
Ensure you are familiar with the following notes when using this release.

‣ If NCCL returns an error code, set the environment variable `NCCL_DEBUG` to `WARN` to receive an explicit error message.
‣ The NCCL 2.x API is different from NCCL 1.x. Some porting may be needed for NCCL 1.x applications to work correctly. Refer to the migration documentation in the NCCL Developer Guide.
‣ Starting in 2.2, NCCL supports collective aggregation. You can put multiple NCCL collective operations in between `ncclGroupStart()` and `ncclGroupEnd()` to enable this feature.

Known Issues

‣ Using multiple processes in conjunction with multiple threads to manage the different GPUs may in some cases cause `ncclCommInitRank` to fail while establishing IPCs (`cudaIpcOpenMemHandle`). This problem does not appear when using only processes or only threads. This issue is fixed in recent driver versions, therefore, consider updating to the latest driver.
‣ NCCL uses CUDA 9 cooperative group launch by default, which may induce increased latencies in multi-threaded programs. See the `NCCL_LAUNCH_MODE` knob to restore the original behavior.
Driver version 390 and later can cause data corruption when used together with GPU Direct RDMA. Disabling GPU Direct RDMA by setting `NCCL_IB_CUDA_SUPPORT=0` or reverting to driver 387 should resolve the issue.

Fixed Issues

- No longer clear the CPU affinity during initialization functions
- Fix various large scale issues
- Reduce the size of the library
- Fix crash or hang with PyTorch relative to the usage of calls to fork
Chapter 11.
NCCL RELEASE 2.1.15

Key Features and Enhancements

This NCCL release includes the following key features and enhancements.

- Added a variable to control InfiniBand Traffic Class and Retry Count.

Using NCCL 2.1.15

Ensure you are familiar with the following notes when using this release.

- The NCCL 2.x API is different from NCCL 1.x. Some porting may be needed for NCCL 1.x applications to work correctly. Refer to the migration documentation in the NCCL Developer Guide.
- Starting in 2.2, NCCL supports collective aggregation. You can put multiple collectives in between `ncclGroupStart()` and `ncclGroupEnd()` to enable this feature.

Known Issues

- If NCCL returns an error code, set the environment variable `NCCL_DEBUG` to `WARN` to receive an explicit error message.
- Using multiple processes in conjunction with multiple threads to manage the different GPUs may in some cases cause `ncclCommInitRank` to fail while establishing IPCs (cudaIpcOpenMemHandle). This problem does not appear when using only processes or only threads.
- NCCL uses CUDA 9 cooperative group launch by default, which may induce increased latencies in multi-threaded programs. See the `NCCL_LAUNCH_MODE` knob to restore the original behavior.

Fixed Issues

- Fixed CPU usage and scheduling of NCCL network threads.
- Fixed CUDA launch crash when mixing different types of GPUs in a node.
- Fixed a performance problem on Skylake CPUs.
- Fixed hanging issues with cudaFree and inter-node communication.
- Restored library installation path to `/usr/lib/x86_64-linux-gnu` in debian packages.
- Fixed RoCEv2 failure when using a non-zero GID.
- No longer link to `stdc++` library statically as this can cause issues with C++ applications.
- Fixed PyTorch hanging issues when using multiple rings and many back-to-back broadcast operations.
Chapter 12.
NCCL RELEASE 2.1.4

Key Features and Enhancements
This NCCL release includes the following key features and enhancements.

‣ Added support for InfiniBand GID selection, enabling the use of RoCE v2.
‣ Added support for InfiniBand Service Level (SL) selection.

Using NCCL 2.1.4
Ensure you are familiar with the following notes when using this release.

‣ The NCCL 2.x API is different from NCCL 1.x. Some porting may be needed for NCCL 1.x applications to work correctly. Refer to the migration documentation in the NCCL Developer Guide.

Known Issues

‣ If NCCL returns an error code, set the environment variable `NCCL_DEBUG` to `WARN` to receive an explicit error message.
‣ Using multiple processes in conjunction with multiple threads to manage the different GPUs may in some cases cause `ncclCommInitRank` to fail while establishing IPCs (`cudaIpcOpenMemHandle`). This problem does not appear when using only processes or only threads.
‣ NCCL uses CUDA® 9 cooperative group launch by default, which may induce increased latencies in multi-threaded programs. See the `NCCL_LAUNCH_MODE` knob in the NCCL Developer Guide to restore the original behavior.
‣ NCCL 2.1.4-1 embeds `libstdc++` and exports its symbols. This can break C++ applications.

Fixed Issues

‣ Fixed bug causing CUDA IPC to fail in some situations.
Fixed bug causing a crash when p2p mappings are exhausted instead of returning an error.
Chapter 13.
NCCL RELEASE 2.1.2

Key Features and Enhancements
This NCCL release includes the following key features and enhancements.

‣ New algorithms for improved latency communication
‣ RoCE support

Using NCCL 2.1.2
Ensure you are familiar with the following notes when using this release.

‣ The NCCL 2.x API is different from NCCL 1.x. Some porting may be needed for NCCL 1.x applications to work correctly. Refer to the migration documentation in the NCCL Developer Guide.

Known Issues

‣ If NCCL returns an error code, set the environment variable `NCCL_DEBUG` to `WARN` to receive an explicit error message.
‣ Using multiple processes in conjunction with multiple threads to manage the different GPUs may in some cases cause `ncclCommInitRank` to fail while establishing IPCs (`cudaIpcOpenMemHandle`). This problem does not appear when using only processes or only threads.
‣ NCCL uses CUDA 9 cooperative group launch by default, which may induce increased latencies in multi-threaded programs. See the `NCCL_LAUNCH_MODE` knob in the NCCL Developer Guide to restore the original behavior.

Fixed Issues

‣ NCCL now uses CUDA 9 cooperative groups to launch the CUDA kernels, fixing a long-standing issue with CUDA and NCCL operations being interleaved and potentially causing hangs.
Chapter 14.
NCCL RELEASE 2.0.5

Key Features and Enhancements

This NCCL release includes the following key features and enhancements.

‣ NCCL 2.0.5 provides support for intra-node and inter-node communication.
‣ NCCL optimizes intra-node communication using NVLink, PCI express, and shared memory.
‣ Between nodes, NCCL implements fast transfers over sockets or InfiniBand verbs.
‣ GPU-to-GPU and GPU-to-Network direct transfers, using the GPU Direct technology, are extensively used when the hardware topology permits it.

Using NCCL 2.0.5

Ensure you are familiar with the following notes when using this release.

‣ The NCCL 2.0 API is different from NCCL 1.x. Some porting may be needed for NCCL 1.x applications to work correctly. Refer to the migration documentation in the NCCL Developer Guide.
‣ NCCL 2.0.5 has the new configuration file support. The NCCL environment variables can now be set in ~/.nccl.conf and /etc/nccl.conf.
‣ Values defined in ~/.nccl.conf take precedence over ones in /etc/nccl.conf.
‣ The syntax for each line of the NCCL configuration file is <NCCL_VAR_NAME>=<VALUE>.

Known Issues

‣ If NCCL returns any error code, set the environment variable NCCL_DEBUG to WARN to receive an explicit error message.
‣ RoCE support is experimental.
‣ Using multiple processes in conjunction with multiple threads to manage the different GPUs may in some cases cause ncclCommInitRank to fail while
establishing IPCs (cudaIpcOpenMemHandle). This problem does not appear when using only processes or only threads.
Chapter 15.
NCCL RELEASE 2.0.4

Key Features and Enhancements
This NCCL release includes the following key features and enhancements.

‣ NCCL 2.0.4 provides support for intra-node and inter-node communication.
‣ NCCL optimizes intra-node communication using NVLink, PCI express, and shared memory.
‣ Between nodes, NCCL implements fast transfers over sockets or InfiniBand verbs.
‣ GPU-to-GPU and GPU-to-Network direct transfers, using the GPU Direct technology, are extensively used when the hardware topology permits it.

Using NCCL 2.0.4
Ensure you are familiar with the following notes when using this release.

‣ The NCCL 2.0 API is different from NCCL 1.x. Some porting may be needed for NCCL 1.x applications to work correctly. Refer to the migration documentation in the NCCL Developer Guide.
‣ NCCL 2.0.4 has the new configuration file support. The NCCL environment variables can now be set in ~/.nccl.conf and /etc/nccl.conf.
‣ Values defined in ~/.nccl.conf take precedence over ones in /etc/nccl.conf.
‣ The syntax for each line of the NCCL configuration file is <NCCL_VAR_NAME>=<VALUE>.

Known Issues
‣ If NCCL returns any error code, set the environment variable NCCL_DEBUG to WARN to receive an explicit error message.
‣ RoCE is not supported.
‣ Using multiple processes in conjunction with multiple threads to manage the different GPUs may in some cases cause ncclCommInitRank to fail while
establishing IPCs (`cudaIpcOpenMemHandle`). This problem does not appear when using only processes or only threads.
Chapter 16.
NCCL RELEASE 2.0.2

Key Features and Enhancements
This NCCL release includes the following key features and enhancements.

‣ NCCL 2.0.2 provides support for intra-node and inter-node communication.
‣ NCCL optimizes intra-node communication using NVLink, PCI express, and shared memory.
‣ Between nodes, NCCL implements fast transfers over sockets or InfiniBand verbs.
‣ GPU-to-GPU and GPU-to-Network direct transfers, using the GPU Direct technology, is extensively used when the hardware topology permits it.

Using NCCL 2.0.2
Ensure you are familiar with the following notes when using this release.

‣ The NCCL 2.0 API is different from NCCL 1.x. Some porting may be needed for NCCL 1.x applications to work correctly. Refer to the migration documentation in the NCCL Developer Guide.

Known Issues
‣ NCCL 2.0.2 is known to not work with CUDA driver 384.40 and later.
‣ If NCCL returns any error code, set the environment variable NCCL_DEBUG to WARN to receive an explicit error message.
‣ NCCL 2.0.2 does not support RoCE, that is, InfiniBand cards using Ethernet as link layer. The presence of an RoCE card on a node will make NCCL fail even when run within the node.
‣ Using multiple processes in conjunction with multiple threads to manage the different GPUs may in some cases cause ncclCommInitRank to fail while establishing IPCs (cudaIpcOpenMemHandle). This problem does not appear when using only processes or only threads.
Notice

THE INFORMATION IN THIS GUIDE AND ALL OTHER INFORMATION CONTAINED IN NVIDIA DOCUMENTATION REFERENCED IN THIS GUIDE IS PROVIDED “AS IS.” NVIDIA MAKES NO WARRANTIES, EXPRESSED, IMPLIED, STATUTORY, OR OTHERWISE WITH RESPECT TO THE INFORMATION FOR THE PRODUCT, AND EXPRESSLY DISCLAIMS ALL IMPLIED WARRANTIES OF NONINFRINGEMENT, MERCHANTABILITY, AND FITNESS FOR A PARTICULAR PURPOSE. Notwithstanding any damages that customer might incur for any reason whatsoever, NVIDIA’s aggregate and cumulative liability towards customer for the product described in this guide shall be limited in accordance with the NVIDIA terms and conditions of sale for the product.

THE NVIDIA PRODUCT DESCRIBED IN THIS GUIDE IS NOT FAULT TOLERANT AND IS NOT DESIGNED, MANUFACTURED OR INTENDED FOR USE IN CONNECTION WITH THE DESIGN, CONSTRUCTION, MAINTENANCE, AND/OR OPERATION OF ANY SYSTEM WHERE THE USE OR A FAILURE OF SUCH SYSTEM COULD RESULT IN A SITUATION THAT THREATENS THE SAFETY OF HUMAN LIFE OR SEVERE PHYSICAL HARM OR PROPERTY DAMAGE (INCLUDING, FOR EXAMPLE, USE IN CONNECTION WITH ANY NUCLEAR, AVIONICS, LIFE SUPPORT OR OTHER LIFE CRITICAL APPLICATION). NVIDIA EXPRESSLY DISCLAIMS ANY EXPRESS OR IMPLIED WARRANTY OF FITNESS FOR SUCH HIGH RISK USES. NVIDIA SHALL NOT BE LIABLE TO CUSTOMER OR ANY THIRD PARTY, IN WHOLE OR IN PART, FOR ANY CLAIMS OR DAMAGES ARISING FROM SUCH HIGH RISK USES.

NVIDIA makes no representation or warranty that the product described in this guide will be suitable for any specified use without further testing or modification. Testing of all parameters of each product is not necessarily performed by NVIDIA. It is customer’s sole responsibility to ensure the product is suitable and fit for the application planned by customer and to do the necessary testing for the application in order to avoid a default of the application or the product. Weaknesses in customer’s product designs may affect the quality and reliability of the NVIDIA product and may result in additional or different conditions and/or requirements beyond those contained in this guide. NVIDIA does not accept any liability related to any default, damage, costs or problem which may be based on or attributable to: (i) the use of the NVIDIA product in any manner that is contrary to this guide, or (ii) customer product designs.

Other than the right for customer to use the information in this guide with the product, no other license, either expressed or implied, is hereby granted by NVIDIA under this guide. Reproduction of information in this guide is permissible only if reproduction is approved by NVIDIA in writing, is reproduced without alteration, and is accompanied by all associated conditions, limitations, and notices.

Trademarks

NVIDIA, the NVIDIA logo, and cuBLAS, CUDA, cuDNN, DALI, DIGITS, DGX, DGX-1, DGX-2, DGX Station, DLProf, Jetson, Kepler, Maxwell, NCCL, Nsight Compute, Nsight Systems, NvCaffe, PerfWorks, Pascal, SDK Manager, Tegra, TensorRT, TensorRT Inference Server, Tesla, TF-TRT, and Volta are trademarks and/or registered trademarks of NVIDIA Corporation in the United States and other countries. Other company and product names may be trademarks of the respective companies with which they are associated.

Copyright

© 2019 NVIDIA Corporation. All rights reserved.

www.nvidia.com