

NVLink 활성화 여부 및 딥러닝 학습 중 NVLINK 통신량 모니터링

실행

- [프로그램 실행]

sh run_test_NVLINK.sh

자동으로 딥러닝에 필요한 파일이 다운로드 되고 딥러닝이 시작됩니다.

(root 권한이 필요합니다. 맨 처음에 Password 입력을 요구합니다.)

기존의 run_test.sh도 수정하여 NVLINK테스트도 하도록 추가했습니다.

- [모니터링 프로그램 실행]

sh show_nvidia_status.sh

(기존에 있던 코드를 다소 수정하여, GPU 간 통신 상태도 모니터링할 수 있도록 했습니다. GPU 간 NVLINK 로 연결되어 있지 않아도 기존 기능은 똑같이 작동합니다.) 딥러닝 프로그램 실행 전, 후 아무 때나 실행하여도 작동합니다.

- [GPU 간 연결상태 확인]

다음 스크린샷은 **nvidia-smi topo -m** 명령어를 입력했을 때 나오는 화면입니다.

프로그램 실행을 시작하면 자동으로 입력되도록 했습니다.

2개의 GPU가 NVLink로 연결되어 있는 경우(TITAN RTX 2GPU with NVLINK)

```
tako@titan-rtx:~$ nvidia-smi topo -m
      GPU0      GPU1      CPU Affinity
GPU0     X        NV2     0-17,36-53
GPU1     NV2       X      18-35,54-71

Legend:
  X    = Self
  SYS  = Connection traversing PCIe as well as the SMP interconnect between NUMA nodes (e.g., QPI/UPI)
  NODE = Connection traversing PCIe as well as the interconnect between PCIe Host Bridges within a NUMA node
  PHB  = Connection traversing PCIe as well as a PCIe Host Bridge (typically the CPU)
  PXB  = Connection traversing multiple PCIe bridges (without traversing the PCIe Host Bridge)
  PIX  = Connection traversing at most a single PCIe bridge
  NV#  = Connection traversing a bonded set of # NVLinks
```

NV2 : 두 개의 GPU가 NVLink로 연결되어 있다는 의미입니다.

2개의 GPU가 NVLink로 연결되어 있지 않은 경우(2080ti 2GPU)

```
tako@2080ti:~$ nvidia-smi topo -m
      GPU0      GPU1      CPU Affinity
GPU0     X        PHB     0-35
GPU1     PHB       X      0-35

Legend:
  X    = Self
  SYS  = Connection traversing PCIe as well as the SMP interconnect between NUMA nodes (e.g., QPI/UPI)
  NODE = Connection traversing PCIe as well as the interconnect between PCIe Host Bridges within a NUMA node
  PHB  = Connection traversing PCIe as well as a PCIe Host Bridge (typically the CPU)
  PXB  = Connection traversing multiple PCIe switches (without traversing the PCIe Host Bridge)
  PIX  = Connection traversing a single PCIe switch
  NV#  = Connection traversing a bonded set of # NVLinks
```

PHB, SYS : NVLink로 연결되어있지 않은 GPU들의 경우 메인보드의 PCIe를 통해 통신.

4개의 GPU가 NVLink로 연결되어 있지 않은 경우 (1080ti 4GPU)

```

| NVIDIA-SMI 418.87.01      Driver Version: 418.87.01      CUDA Version: 10.1      |
|-----+-----+-----+-----+-----+-----+-----+-----+
| GPU  Name      Persistence-M| Bus-Id        Disp.A | Volatile Uncorr. ECC |
| Fan  Temp     Perf   Pwr:Usage/Cap|  Memory-Usage | GPU-Util  Compute M. |
|-----+-----+-----+-----+-----+-----+-----+
|  0    GeForce GTX 108...  Off | 00000000:02:00:0 Off |             N/A     |
| 31%   59C     P2    189W / 250W | 9274MiB / 11178MiB |    91%    Default   |
|-----+-----+-----+-----+-----+-----+
|  1    GeForce GTX 108...  Off | 00000000:03:00:0 Off |             N/A     |
| 32%   60C     P2    162W / 250W | 8679MiB / 11178MiB |    45%    Default   |
|-----+-----+-----+-----+-----+-----+
|  2    GeForce GTX 108...  Off | 00000000:82:00:0 Off |             N/A     |
| 30%   58C     P2    154W / 250W | 8673MiB / 11178MiB |    42%    Default   |
|-----+-----+-----+-----+-----+-----+
|  3    GeForce GTX 108...  Off | 00000000:83:00:0 Off |             N/A     |
| 32%   60C     P2    185W / 250W | 8673MiB / 11178MiB |    44%    Default   |
|-----+-----+-----+-----+-----+-----+
|
| Processes:
| GPU      PID     Type    Process name      GPU Memory
|      |      |      |      |      |      |
|-----+-----+-----+-----+-----+-----+
|      0     19183    C      python            8671MiB
|      0     35787    C      python3           593MiB
|      1     19183    C      python            8669MiB
|      2     19183    C      python            8663MiB
|      3     19183    C      python            8663MiB
|-----+-----+-----+-----+-----+
|      GPU0      GPU1      GPU2      GPU3      CPU Affinity
|-----+-----+-----+-----+-----+
| GPU0      X        PHB       SYS       SYS       0-9,20-29
| GPU1      PHB       X        SYS       SYS       0-9,20-29
| GPU2      SYS       SYS       X        PHB       10-19,30-39
| GPU3      SYS       SYS       PHB       X        10-19,30-39
|
Legend:
X      = Self
SYS    = Connection traversing PCIe as well as the SMP interconnect between NUMA nodes (e.g., QPI/UPI)
NODE   = Connection traversing PCIe as well as the interconnect between PCIe Host Bridges within a NUMA node
PHB    = Connection traversing PCIe as well as a PCIe Host Bridge (typically the CPU)
PXB    = Connection traversing multiple PCIe switches (without traversing the PCIe Host Bridge)
PIX    = Connection traversing a single PCIe switch
NV#    = Connection traversing a bonded set of # NVLinks

```

딥러닝은 train과 test 과정을 반복해서 거치게 되는데 한 바퀴(epoch)를 돌 때마다,

GPU간 NVLink를 통한 통신량을 출력합니다.

NVLink를 통한 통신이 정상적으로 이루어지고 있다면 RX/TX (받고 주는 통신량) 수치가 계속해서 오르게 됩니다.

(NVLink로 연결되어 있지 않다면 아무 숫자도 뜨지 않습니다.)

```
Train Epoch: 1 [0/50000 (0%)] Loss: 4.159657
Train Epoch: 1 [6400/50000 (13%)] Loss: 3.796069
Train Epoch: 1 [12800/50000 (26%)] Loss: 3.614151
Train Epoch: 1 [19200/50000 (38%)] Loss: 3.532341
Train Epoch: 1 [25600/50000 (51%)] Loss: 3.539228
Train Epoch: 1 [32000/50000 (64%)] Loss: 3.675136
Train Epoch: 1 [38400/50000 (77%)] Loss: 3.594474
Train Epoch: 1 [44800/50000 (90%)] Loss: 3.480831
GPU 0: TITAN RTX (UUID: GPU-e0444474-a2fb-434e-de9d-aa7440cf5e55)
      Link 0: Rx0: 49020 KBytes, Tx0: 202616 KBytes
      Link 1: Rx0: 49007 KBytes, Tx0: 202610 KBytes
GPU 1: TITAN RTX (UUID: GPU-179fd50e-cb3d-7f2f-29c9-9a4a06599508)
      Link 0: Rx0: 202616 KBytes, Tx0: 49020 KBytes
      Link 1: Rx0: 202610 KBytes, Tx0: 49007 KBytes

Test set: Average loss: 3.4555, Accuracy: 4117/10000 (41%)

Train Epoch: 2 [0/50000 (0%)] Loss: 3.555848
Train Epoch: 2 [6400/50000 (13%)] Loss: 3.472954
Train Epoch: 2 [12800/50000 (26%)] Loss: 3.442425
Train Epoch: 2 [19200/50000 (38%)] Loss: 3.439695
Train Epoch: 2 [25600/50000 (51%)] Loss: 3.462113
Train Epoch: 2 [32000/50000 (64%)] Loss: 3.336234
Train Epoch: 2 [38400/50000 (77%)] Loss: 3.500667
Train Epoch: 2 [44800/50000 (90%)] Loss: 3.457918
GPU 0: TITAN RTX (UUID: GPU-e0444474-a2fb-434e-de9d-aa7440cf5e55)
      Link 0: Rx0: 98143 KBytes, Tx0: 445752 KBytes
      Link 1: Rx0: 98116 KBytes, Tx0: 445741 KBytes
GPU 1: TITAN RTX (UUID: GPU-179fd50e-cb3d-7f2f-29c9-9a4a06599508)
      Link 0: Rx0: 445752 KBytes, Tx0: 98143 KBytes
      Link 1: Rx0: 445741 KBytes, Tx0: 98116 KBytes

Test set: Average loss: 3.4459, Accuracy: 4268/10000 (43%)
```

- 프로그램은 총 20바퀴 (epoch)를 돌도록 했습니다.

성능 향상 측정 결과

	CPU	GPU
서버 1	E5-2695v4	TITAN-RTX 24G x 2
서버 2	Xeon Gold 5225	TITAN-RTX 24G x 2 (NVLink)

위 환경에서 측정했을 때 NVLink를 장착한 경우 20~30%가량 학습 속도면에서 성능향상이 있었습니다.

[Model : ResNet152 / Dataset: CIFAR10 / batch size: 256 / PyTorch nn.DataParallel 사용]

Multi GPU 사용 시, GPU 들이 각각 나누어서 한 작업을 함쳐야 할 때, NVLink 를 사용하면 GPU 간 직접 통신하는 루트를 열어줘서 속도가 빨라지게 됨.

(부록) GPU간 NVLink를 이용한 통신량 모니터링 방법

카운터를 시작한 후, 코드 실행 중,

Counter를 통해 GPU간 NVLink를 통한 데이터의 통신량 확인

NVLink counter 시작

```
nvidia-smi nvlink -sc 0bz
```

Counter 초기화

```
nvidia-smi nvlink -r 0
```

Counter 확인

```
nvidia-smi nvlink -g 0
```

Counter 닫기

```
nvidia-smi nvlink -sc 0bn
```

```
(base) oem@BAR0:~$ sudo nvidia-smi nvlink -g 0
GPU 0: TITAN RTX (UUID: GPU-fcf64522-1b85-33ad-46f1-26fbalad7f0c)
  Link 0: Rx0: 824999 KBytes, Tx0: 872359 KBytes
  Link 1: Rx0: 824976 KBytes, Tx0: 872369 KBytes
GPU 1: TITAN RTX (UUID: GPU-286a8312-8494-0412-b646-159571073192)
  Link 0: Rx0: 872359 KBytes, Tx0: 824999 KBytes
  Link 1: Rx0: 872369 KBytes, Tx0: 824976 KBytes
(base) oem@BAR0:~$ sudo nvidia-smi nvlink -g 0
GPU 0: TITAN RTX (UUID: GPU-fcf64522-1b85-33ad-46f1-26fbalad7f0c)
  Link 0: Rx0: 3122868 KBytes, Tx0: 5010998 KBytes
  Link 1: Rx0: 3122745 KBytes, Tx0: 5011011 KBytes
GPU 1: TITAN RTX (UUID: GPU-286a8312-8494-0412-b646-159571073192)
  Link 0: Rx0: 5010998 KBytes, Tx0: 3122868 KBytes
  Link 1: Rx0: 5011011 KBytes, Tx0: 3122745 KBytes
(base) oem@BAR0:~$ sudo nvidia-smi nvlink -g 0
GPU 0: TITAN RTX (UUID: GPU-fcf64522-1b85-33ad-46f1-26fbalad7f0c)
  Link 0: Rx0: 3345053 KBytes, Tx0: 6953246 KBytes
  Link 1: Rx0: 3344890 KBytes, Tx0: 6953241 KBytes
GPU 1: TITAN RTX (UUID: GPU-286a8312-8494-0412-b646-159571073192)
  Link 0: Rx0: 6953246 KBytes, Tx0: 3345053 KBytes
  Link 1: Rx0: 6953241 KBytes, Tx0: 3344890 KBytes
(base) oem@BAR0:~$ sudo nvidia-smi nvlink -g 0
GPU 0: TITAN RTX (UUID: GPU-fcf64522-1b85-33ad-46f1-26fbalad7f0c)
  Link 0: Rx0: 4320857 KBytes, Tx0: 7974093 KBytes
  Link 1: Rx0: 4320667 KBytes, Tx0: 7974099 KBytes
GPU 1: TITAN RTX (UUID: GPU-286a8312-8494-0412-b646-159571073192)
  Link 0: Rx0: 7974093 KBytes, Tx0: 4320859 KBytes
  Link 1: Rx0: 7974099 KBytes, Tx0: 4320669 KBytes
(base) oem@BAR0:~$ sudo nvidia-smi nvlink -g 0
GPU 0: TITAN RTX (UUID: GPU-fcf64522-1b85-33ad-46f1-26fbalad7f0c)
  Link 0: Rx0: 4835374 KBytes, Tx0: 8512359 KBytes
  Link 1: Rx0: 4835169 KBytes, Tx0: 8512371 KBytes
GPU 1: TITAN RTX (UUID: GPU-286a8312-8494-0412-b646-159571073192)
  Link 0: Rx0: 8512359 KBytes, Tx0: 4835374 KBytes
  Link 1: Rx0: 8512371 KBytes, Tx0: 4835169 KBytes
(base) oem@BAR0:~$ sudo nvidia-smi nvlink -g 0
GPU 0: TITAN RTX (UUID: GPU-fcf64522-1b85-33ad-46f1-26fbalad7f0c)
  Link 0: Rx0: 5145856 KBytes, Tx0: 8837173 KBytes
  Link 1: Rx0: 5145642 KBytes, Tx0: 8837188 KBytes
GPU 1: TITAN RTX (UUID: GPU-286a8312-8494-0412-b646-159571073192)
  Link 0: Rx0: 8837173 KBytes, Tx0: 5145856 KBytes
  Link 1: Rx0: 8837188 KBytes, Tx0: 5145642 KBytes
```