Georgia Tech School of Electrical and Computer Engineering
College of Engineering

SYNERGY

http://synergy.ece.gatech.edu

STRA SIM

Exercise 3: Comparing Systems

Will Won
Ph.D. Student, School of Computer Science
Georgia Institute of Technology
william.won@gatech.edu

Acknowledgments: Srinivas Sridharan (Facebook), Sudarshan Srinivasan (Intel)

Agenda

Time (CET)	Time (ET)	Topic	Presenter
15:00 – 16:00	9:00 – 10:00	**Introduction to Distributed Deep Learning Training Platforms**	Tushar Krishna
16:00 – 17:00	10:00 – 11:00	**ASTRA-sim**	Saeed Rashidi
17:00 – 17:10	11:00 – 11:10	**Break**	
17:10 – 17:50	11:10 – 11:50	**Demo and Exercises**	William Won and Taekyung Heo
17:50 – 18:00	11:50 – 12:00	**Extensions and Future Development**	Tushar Krishna and Saeed Rashidi

Tutorial Website

includes agenda, slides, ASTRA-sim installation instructions (via source + docker image)
https://astra-sim.github.io/tutorials/asplos-2022

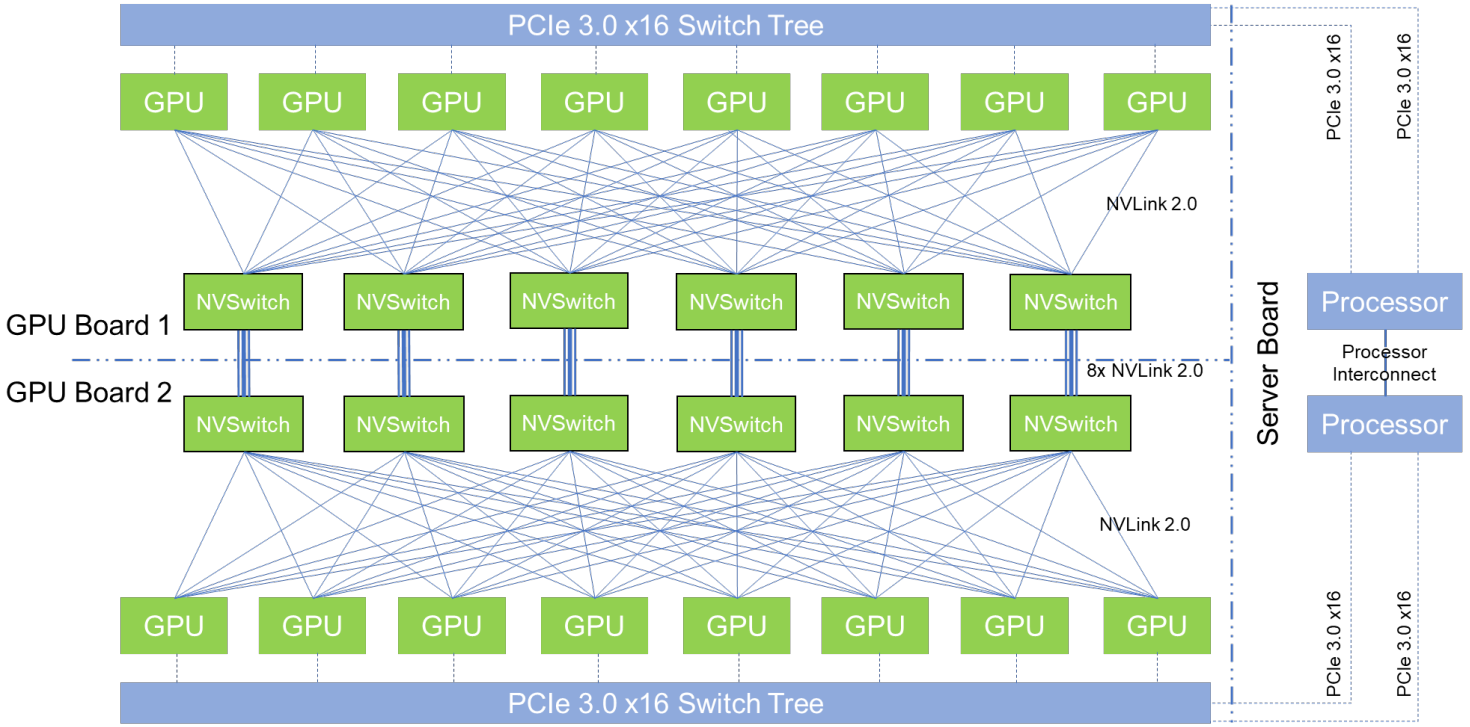
Attention: Tutorial is being recorded

Objective

- Representing real systems using ASTRA-sim
  - NVIDIA DGX-2 Pods
  - Google Cloud TPU
- Running real DL workload benchmarks
  - Vision model (VGG-16)
  - Language model (GPT-3)
- Comparing ASTRA-sim results

NVIDIA DGX-2 Architecture

- 16 V100 GPUs
- Connected Using NVSwitch / NVLink
- 100 GbE InfiniBand Scale-out per 2 GPUs (i.e., effectively 50 GbE per GPU)



- NVSwitch:
  - 25 GB/s per NVLink
  - 6 NVLinks per GPU
- InfiniBand Switch:
  - 6.25 GB/s

https://docs.it4i.cz/dgx2/introduction/

Representing DGX-2

- 16 DGX-2 connected (**total 256 GPUs**)

`inputs/dgx2.json`

```
{
  "dimensions-count": 2,
  "topologies-per-dim": ["Switch", "Switch"],
  "units-count": [16, 16],
  "links-count": [6, 1],
  "link-latency": [500, 500],
  "link-bandwidth": [25, 6.25]
}
```

2D network

Switch_Switch Topology

16x16 GPUs (total 256 GPUs)

[6, 1] links per GPU, dim

link latency

link bandwidth

Representing DGX-2

- 16 DGX-2 connected (**total 256 GPUs**)

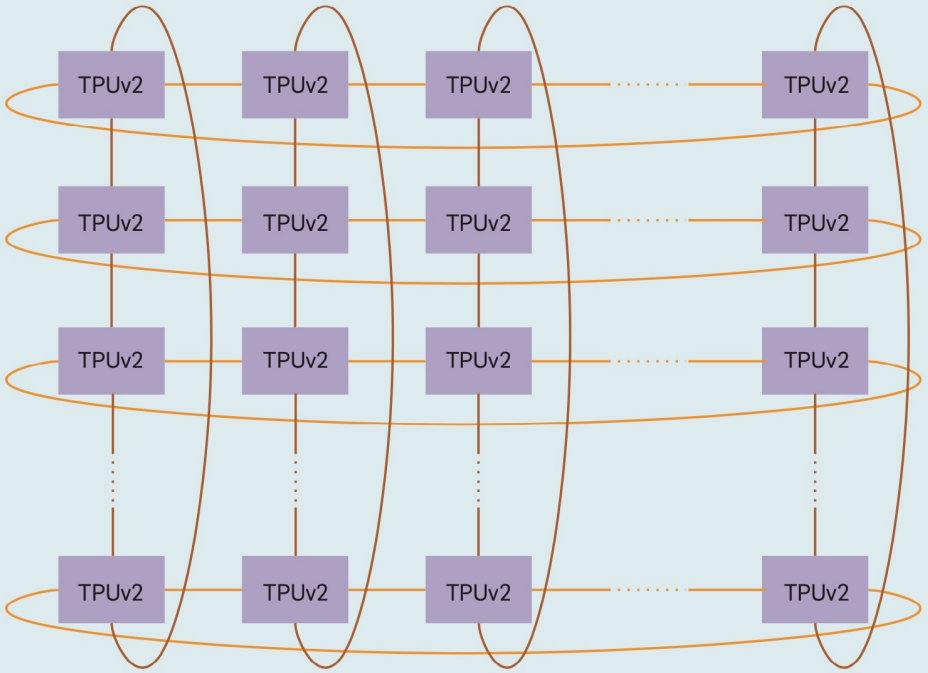
`inputs/dgx2.txt`

```
scheduling-policy: LIFO
endpoint-delay: 10
active-chunks-per-dimension: 1
preferred-dataset-splits: 4
boost-mode: 1
all-reduce-implementation: halvingDoubling_halvingDoubling
all-gather-implementation: halvingDoubling_halvingDoubling
reduce-scatter-implementation: halvingDoubling_halvingDoubling
all-to-all-implementation: direct_direct
collective-optimization: localBWAware
```

Hierarchical All-Reduce Algorithm

Google Cloud TPU Architecture

Figure 1. A 2D-torus topology. TPUv2 uses a 16x16 2D torus.



- 16×16 TPUv2 (Total 256 TPUs)
- 2D Torus Topology
- Inter-core Interconnect (ICI)
  - 496 Gbps (= 62 GB/s)

N. Jouppi *et al.*, "A Domain-Specific Supercomputer for Training Deep Neural Networks," Communications of the ACM, 63, 7, 67-78.

Representing Cloud TPU

- 16×16 TPUv2 (Total 256 TPUs)

`inputs/tpu.json`

```
{
  "dimensions-count": 2,
  "topologies-per-dim": ["Ring", "Ring"],
  "units-count": [16, 16],
  "links-count": [2, 2],
  "link-latency": [500, 500],
  "link-bandwidth": [62, 62]
}
```

2D network

Ring_Ring Topology (2D Torus)

16x16 TPUs (total 256 TPUs)

[2, 2] links per TPU, dim

link latency

62GB/s link bandwidth

Representing Cloud TPU

- 16×16 TPUv2 (Total 256 TPUs)

`inputs/tpu.txt`

```
scheduling-policy: LIFO
endpoint-delay: 10
active-chunks-per-dimension: 1
preferred-dataset-splits: 4
boost-mode: 1
all-reduce-implementation: ring_ring
all-gather-implementation: ring_ring
reduce-scatter-implementation: ring_ring
all-to-all-implementation: direct_direct
collective-optimization: localBWAware
```

Hierarchical All-Reduce Algorithm

Representing Workload

Metadata		Forward			Input grad			Weight grad			Layer
Layer Name	(rsvd.)	Compute Time	Comm. Type	Comm. size	Compute Time	Comm. Type	Comm. Size	Compute Time	Comm. Type	Comm. Size	Delay
allreduce	-1	1	NONE	0	1	NONE	0	1	ALLREDUCE	1048576	1

- Compute Time
- Communication Type
- Communication Size

Representing Workload

	V100	TPUv2
Peak Tensor Performance (TFLOPS)	112	46

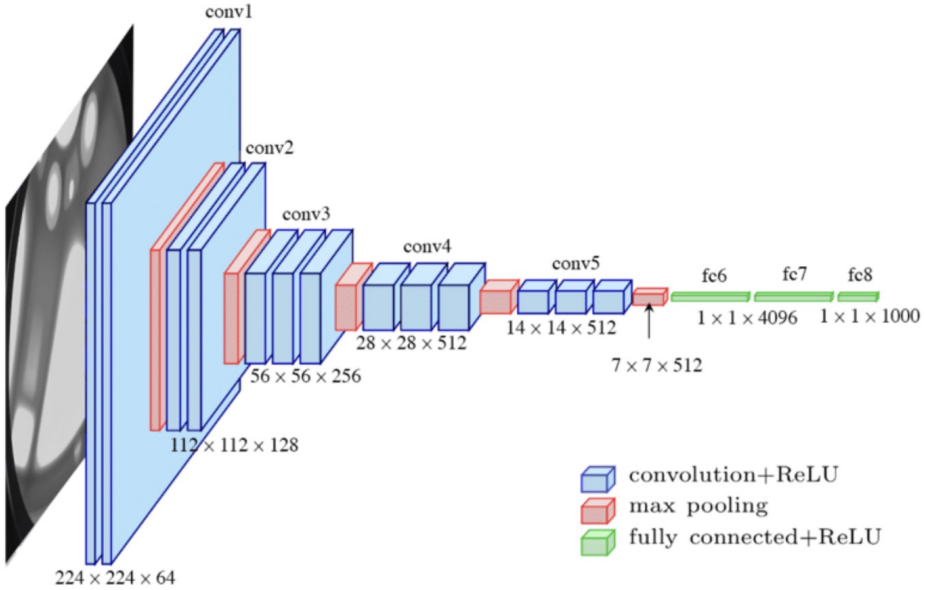
- V100 is **2.43x** faster than TPUv2
- *i.e.,* V100 **compute time** is **0.41x** of TPUv2

Representing Workload

- VGG-16 first layer: (50,176 × 27) × (27 × 64)
  - Total 173,408,256 operations
  - TPUv2: 46 TFLOPS (46×2^{40} op/s)
  - **3429 ns**
- Can leverage **Workload Generator** or other performance estimations
- Communication: Filter
  - Size: ((3 × 3) × 3 + 1) × 64 = 1,792

filter, input channel, bias, output channel

  - 1,792 × 2B = 3,584 (=**3.5 KB**)



https://medium.com/mlearning-ai/an-overview-of-vgg16-and-nin-models-96e4bf398484

Representing Workload

`inputs/vgg16.txt`

```
DATA
16
block1_conv1 -1 3429 NONE 0 3429 NONE 0 3429 ALLREDUCE 3584 1
```

Data Parallel

#layers

1st layer

Metadata		Forward			Input grad			Weight grad			Layer
Layer Name	(rsvd.)	Compute Time	Comm. Type	Comm. size	Compute Time	Comm. Type	Comm. Size	Compute Time	Comm. Type	Comm. Size	Delay
block1_conv1	-1	**3429**	NONE	0	**3429**	NONE	0	**3429**	**ALLREDUCE**	**3584**	1

Estimated Compute Time

Data-Parallel

3.5 KB

Running Experiment

- Objective:
  - Run VGG-16
  - On DGX-2 Pod and Cloud TPU

- V100 **compute time** is **0.41x** of TPUv2

```
"${BINARY}" \
    --run-name="DGX2-VGG16" \
    --network-configuration="${NETWORK}" \
    --system-configuration="${SYSTEM}" \
    --workload-configuration="${WORKLOAD}" \
    --compute-scale="0.41" \
    --path="${RESULT_DIR}/"
```

DGX-2 Configuration

V100 compute time is **0.41x** of TPUv2

Running Experiment

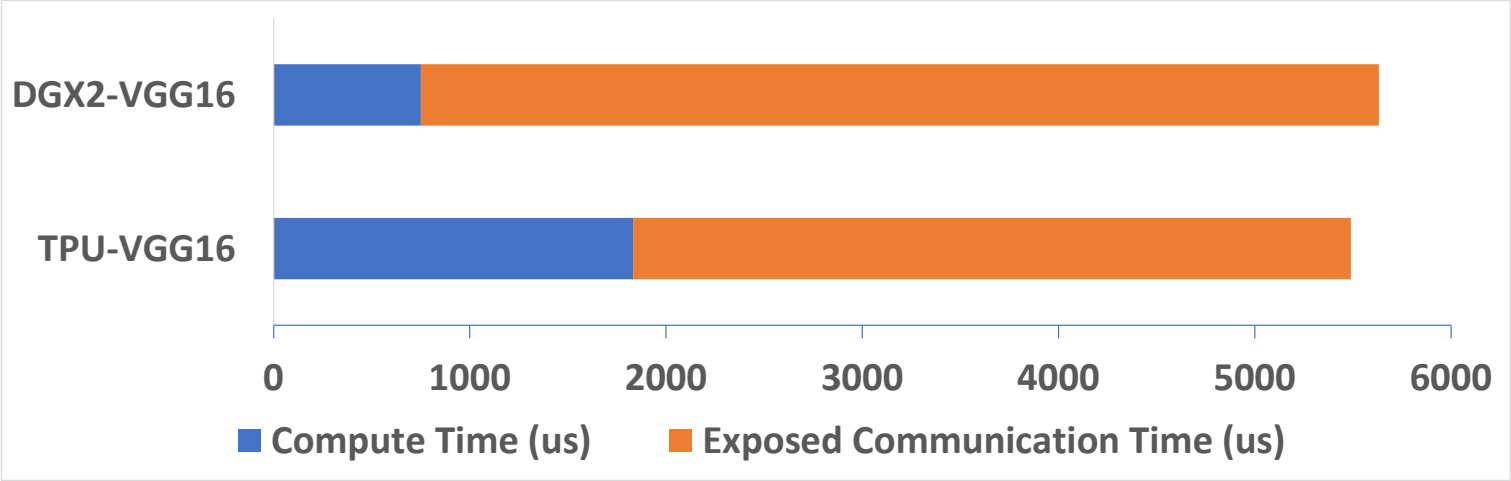
- Objective:
  - Run **VGG-16**
  - On **DGX-2** Pod and **Cloud TPU**

```
$ cd exercise_3/
$ ./build.sh
$ ./exercise_3_1.sh
```

Understanding Results

`result_1/tutorial_result.csv`

Name	Total Time (us)	Compute Time (us)	Exposed Communication Time (us)	Total Message Size (MB)
DGX2-VGG16	**5632.316**	751.019	4881.297	525.729748
TPU-VGG16	**5489.225**	1831.809	3657.416	525.730019



Running Experiment

- Objective:
  - Run **GPT-3** (First 3 Transformer layers)
  - On DGX-2 Pod and Cloud TPU

```
$ ./build.sh
$ ./exercise_3_2.sh
```

Understanding Results

`result_2/tutorial_result.csv`

Name	Total Time (us)	Compute Time (us)	Exposed Communication Time (us)	Total Message Size (MB)
DGX2-GPT3	**787767.34**	575821.446	211945.894	32943.252
TPU-GPT3	**1655238.43**	1404442.610	250795.814	32943.252