Training Neural Networks with hundreds of GPUs on Graham and Cedar

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Outlines

- What is new?
  - Hardware/software
- Where to run a job?
  - Node types and scheduling policies
- Different methods for managing variables
  - Parameter server or replicated?
  - CPU memory or GPU memory?
- Interconnection and I/O bottleneck
  - TCP/IP or IB, Lustre or local
- Examples

New systems

system	GPU type	#GPU devices	target jobs
Graham	P100-12g	320 (2 per node)	*Single GPU, MultiGPU, Distributed*
Cedar	P100-12g/ 16g	584 (4 per node)	*Single GPU, MultiGPU, Distributed*
Minsky	P100- NVLINK	4	*Experiment*

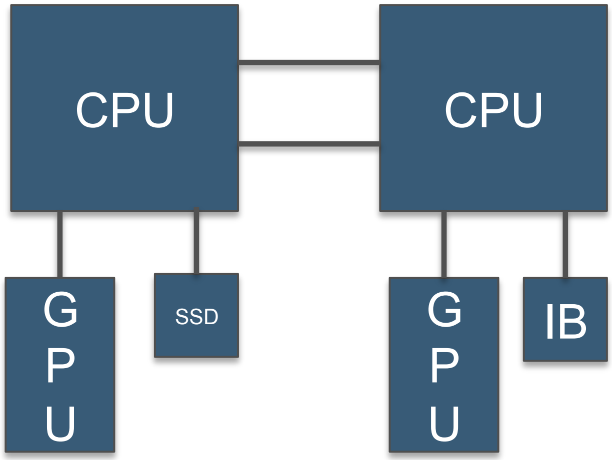
Softwares

- Caffe2, TensorFlow, Theano, Torch
- More about software:
  - https://docs.computecanada.ca/wiki/AI_and_Machine_Learning

Node Types

Graham GPU nodes:

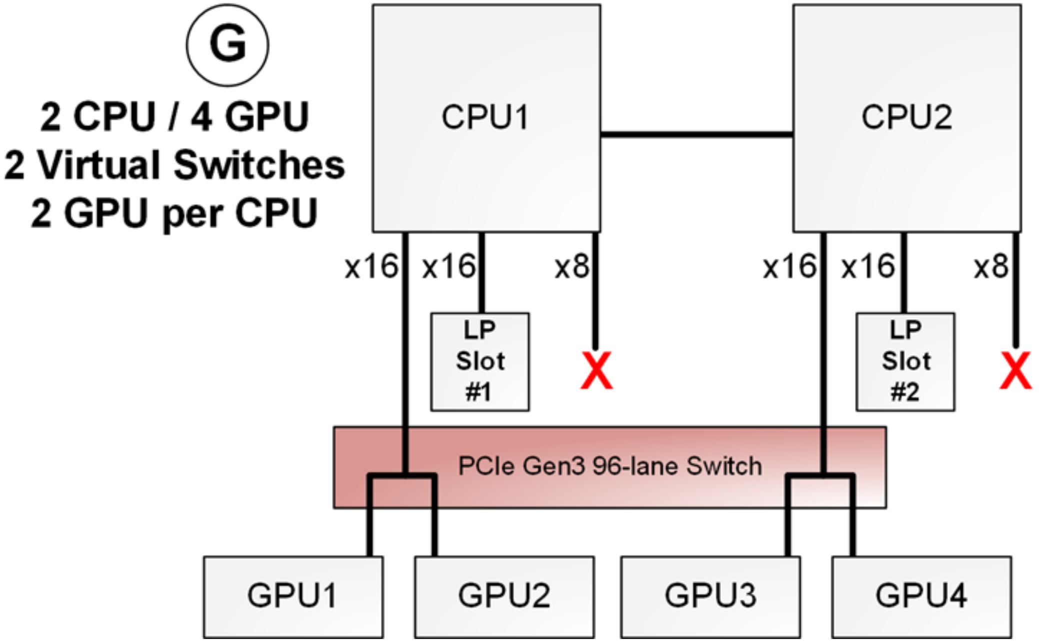
- 2 x E5-2683v4, 32 CPU cores, 128GB memory
- 2 x P100-12GB-PCIE, one each CPU socket
- IB FDR 56Gb/s, 1.6T NVMe SSD
- Accept single GPU jobs and whole node(s) jobs
- SLRUM 2 GPUs request: #SBATCH --gres=gpu:2



Node Types

Cedar Base GPU nodes:

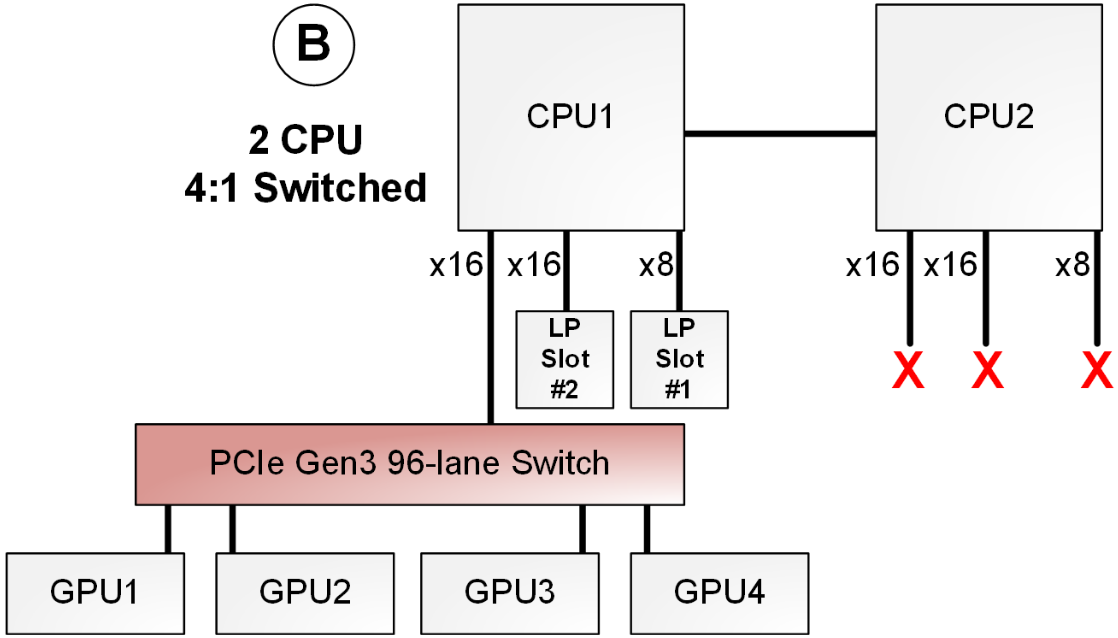
- 2 x E5-2650v4, 24 CPU cores, 128GB memory
- 4 x P100-12GB-PCIE, two each CPU socket
- Intel OPA 100Gb/s (LP slot), 800GB SATA SSD
- Accept single GPU jobs and whole node(s) jobs
- SLRUM 4 GPUs request: #SBATCH --gres=gpu:4



Node Types

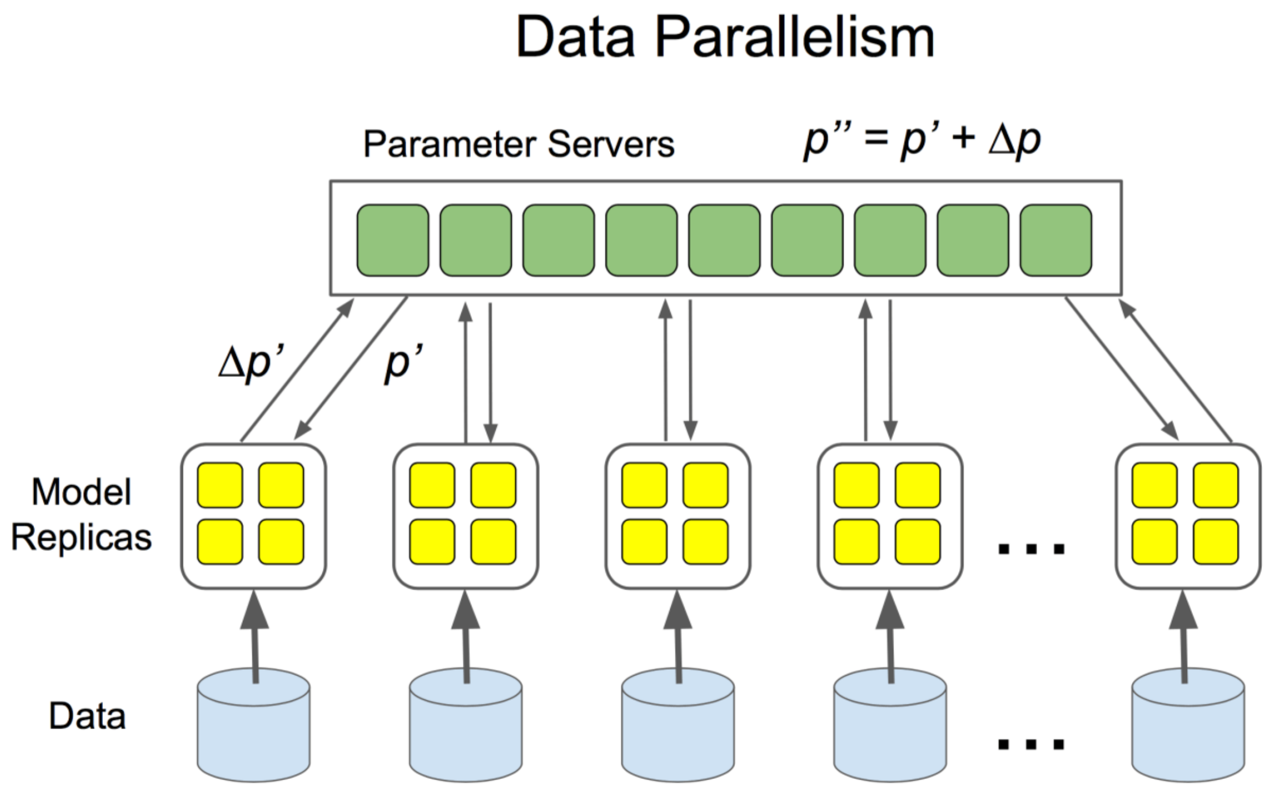
Cedar Large GPU nodes: (best for ML/DL)

- 2 x E5-2650v4, 24 CPU cores, 256GB memory
- 4 x P100-16GB-PCIE, all under single CPU socket
- Intel OPA 100Gb/s (LP slot), 800GB SATA SSD
- Accept whole node(s) jobs, single GPU jobs less than 24 hours
- SLRUM 4 GPUs request: #SBATCH --gres=gpu:lgpu:4



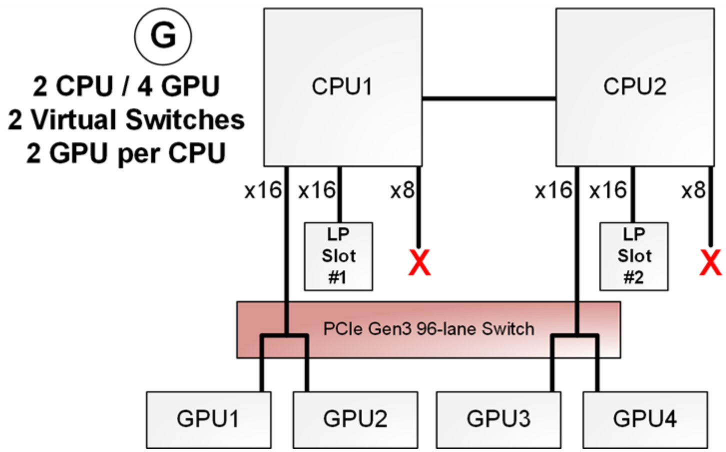
Different methods for managing variables

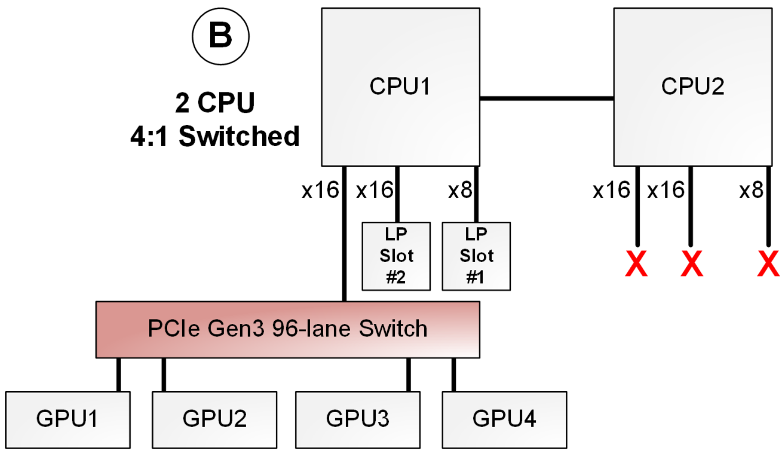
Parameter Server(s):



Different methods for managing variables

Parameter Server(s) in CPU or GPU?





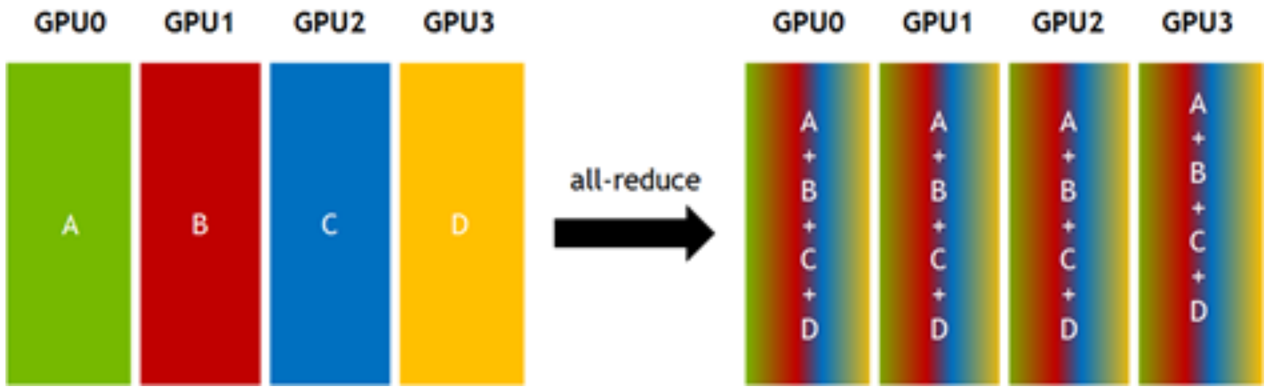
- Bottleneck is between GPUs from different sockets
- Good for CPU as server (Server operations can be overlapped with GPU training)

- Bottleneck is between CPU and GPU
- Good for GPU as server

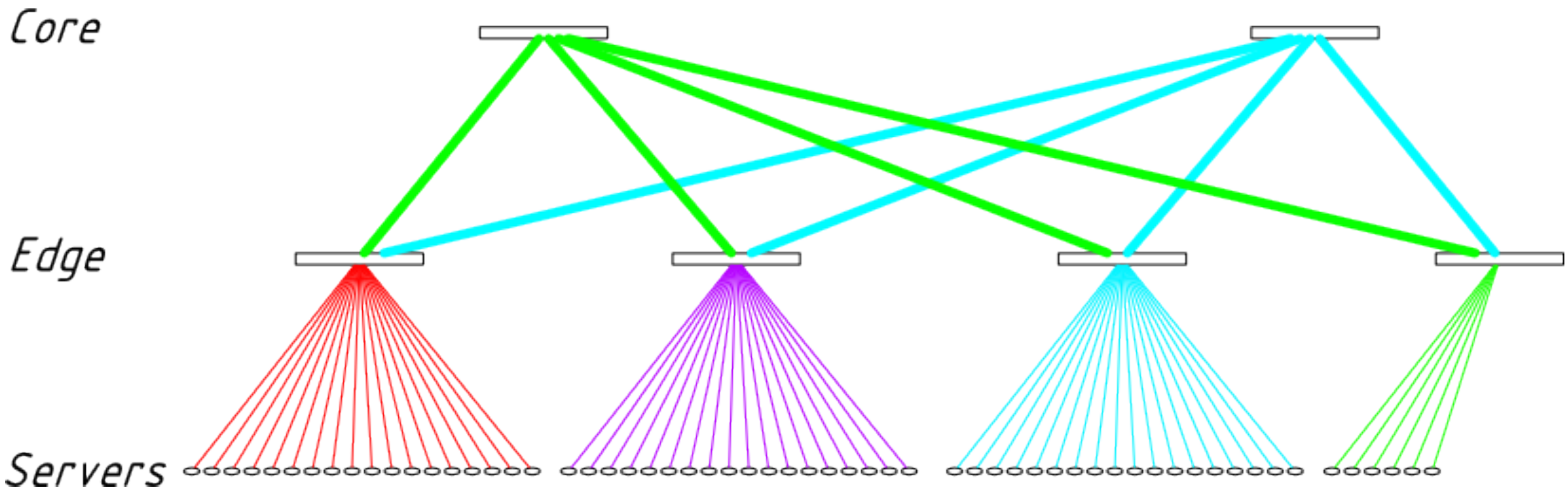
Different methods for managing variables

Replicated parameters on all GPUs:

- Updating parameters = all_reduce operation
- Total bandwidth between GPUs matters
- Cedar Large GPU node has the highest total PCIe bandwidth
- NVIDIA NCCL can be used, but not always the best, do benchmarking



Interconnection



Topology: Fat-Tree for both Graham and Cedar

Blocking factor:

- non-blocking for 32 servers under same “Edge” switch
- 2:1 blocking for Cedar when crossing switches
- 8:1 blocking for Graham when crossing switches

Network Protocols

TCP or IB (Infiniband)?

- IPoIB (IP over Infiniband) performance is ~30-40Gb/s

- Tensorflow:
  - gRPC (runs on top of TCP) by default
  - IB is supported as “third party contribution”
- Caffe2:
  - TCP only
  - IB will be supported in the future
- pyTorch:
  - initially MPI and raw TCP sockets, later RDMA
- Theano:
  - IB is supported via third party projects (e.g. Theano-MPI)

Choosing the correct interface when using TCP:

- Multiple network interfaces when run command “ifconfig”
- Should always use “ib0” interface’s IP address
- Other interfaces are very slow (some with only 1Gb/s)

Understanding I/O bottleneck

I/O will easily become bottleneck when training with many GPUs

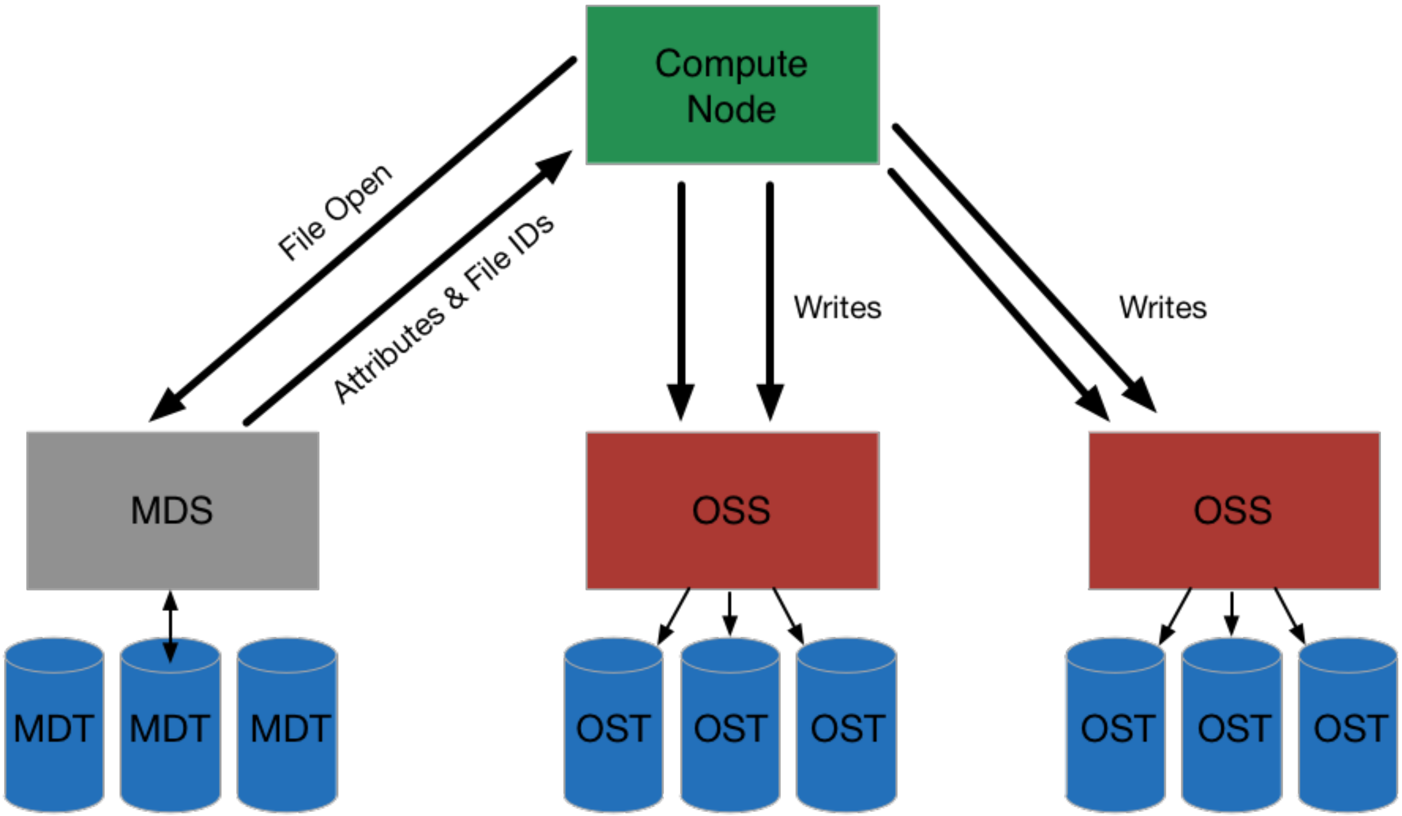
- 1 P100 GPU can train Resnet-50 with a speed of 200 images/s (40MB/s)

- Lustre file system (/project and /scratch):
  - Able to achieve 30GB/s using hundreds of clients to load a huge file
  - Loading imagenet LMDB file sometime can only reach 300MB/s
  - Random accessing is even slower, can be less than 100MB/s

- Local file system (/localscratch):
  - SSD based, 800GB on Cedar, 1.6TB on Graham
  - Cedar has SATA SSD (~500MB/s), Graham has NVMe SSD (>1GB/s)
  - Need to copy the data every time before training starts
  - Local storage will be cleaned after job is finished/killed

- Highly suggest to copy the data to local SSD for faster random access
  - Original data can be stored on multiple OSTs on /project or /scratch to achieve higher throughput
  - Details on next page…

Lustre parallel file system



- By default, single file is stored in a single OST
- Commands to stripe the file across OSTs:

- lfs setstripe -s 1m -c 8 <file> (stripe size 1MB, count 8 OSTs)
- cp <target> <file> (above command only creates empty file)
- lfs getstripe <file> (to check)

Examples

Common problems:

- What ML/DL tools are available?
- How to require hardware resources via SLRUM?
- How to launch the program on all nodes?
- How to use local storage?
- How to get correct IP address?

THANK YOU!

Q&A