Deep Learning on SHARCNET:

From CPU to GPU cluster

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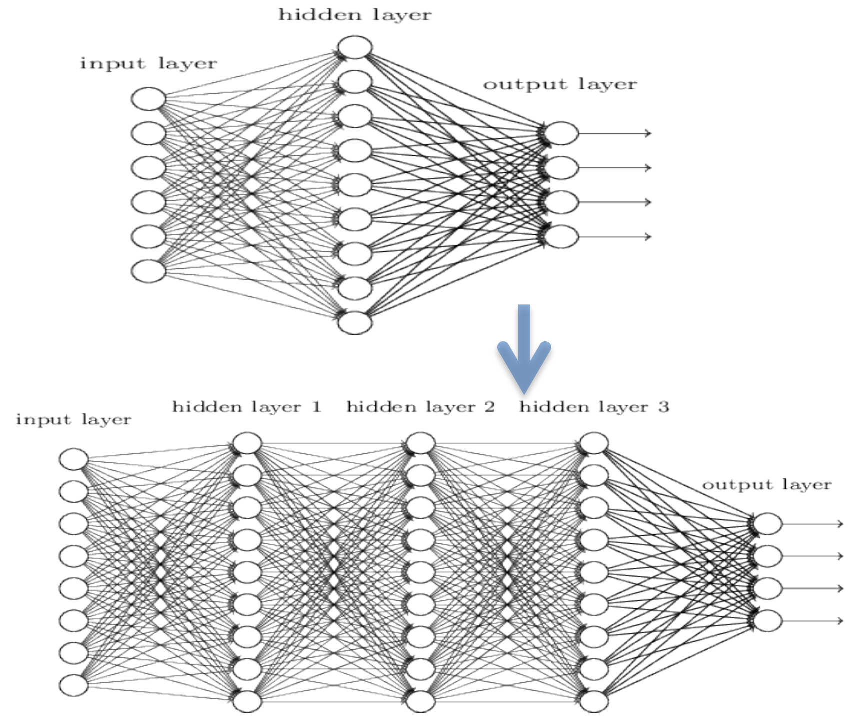
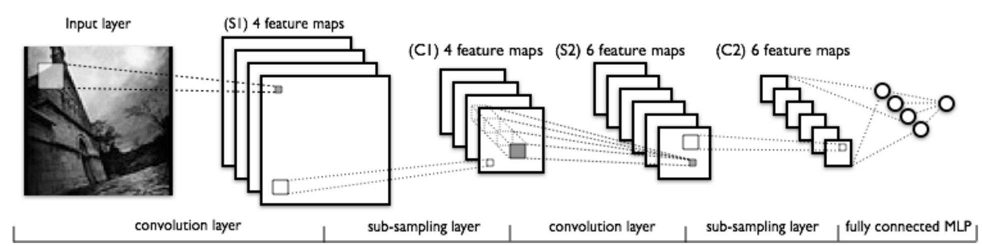
List of Topics:

- Deep Learning basics
  - Typical models, computational needs
- HPC and DL
  - Why GPU cluster?
    - Theoretical performance: CPU vs. GPU
    - Demos and benchmarks on DL tools with real world problem
  - Why & how to go deeper and bigger?
    - Monk hardware topology
    - Intra-node comm (GPUDirect P2P)
    - Inter-node comm (CUDA-aware MPI)

Deep Learning basics

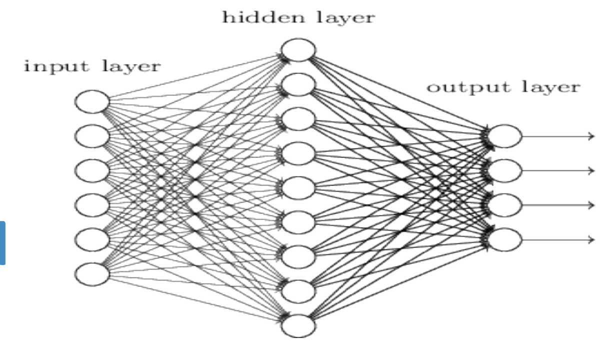
- Multiple layer networks:
  - RBMs(Restricted Boltzmann Machines), DBN(Deep Belief Network)
  - Convolutional neural network



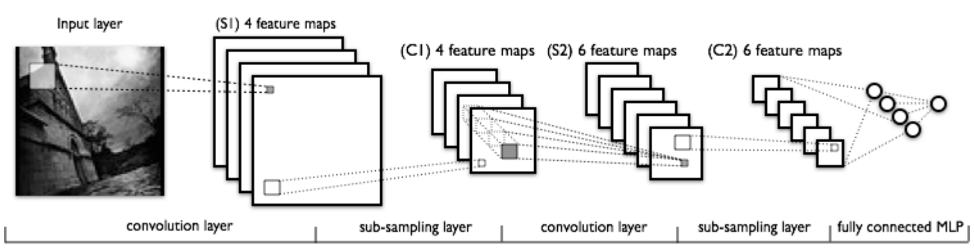


Computational needs

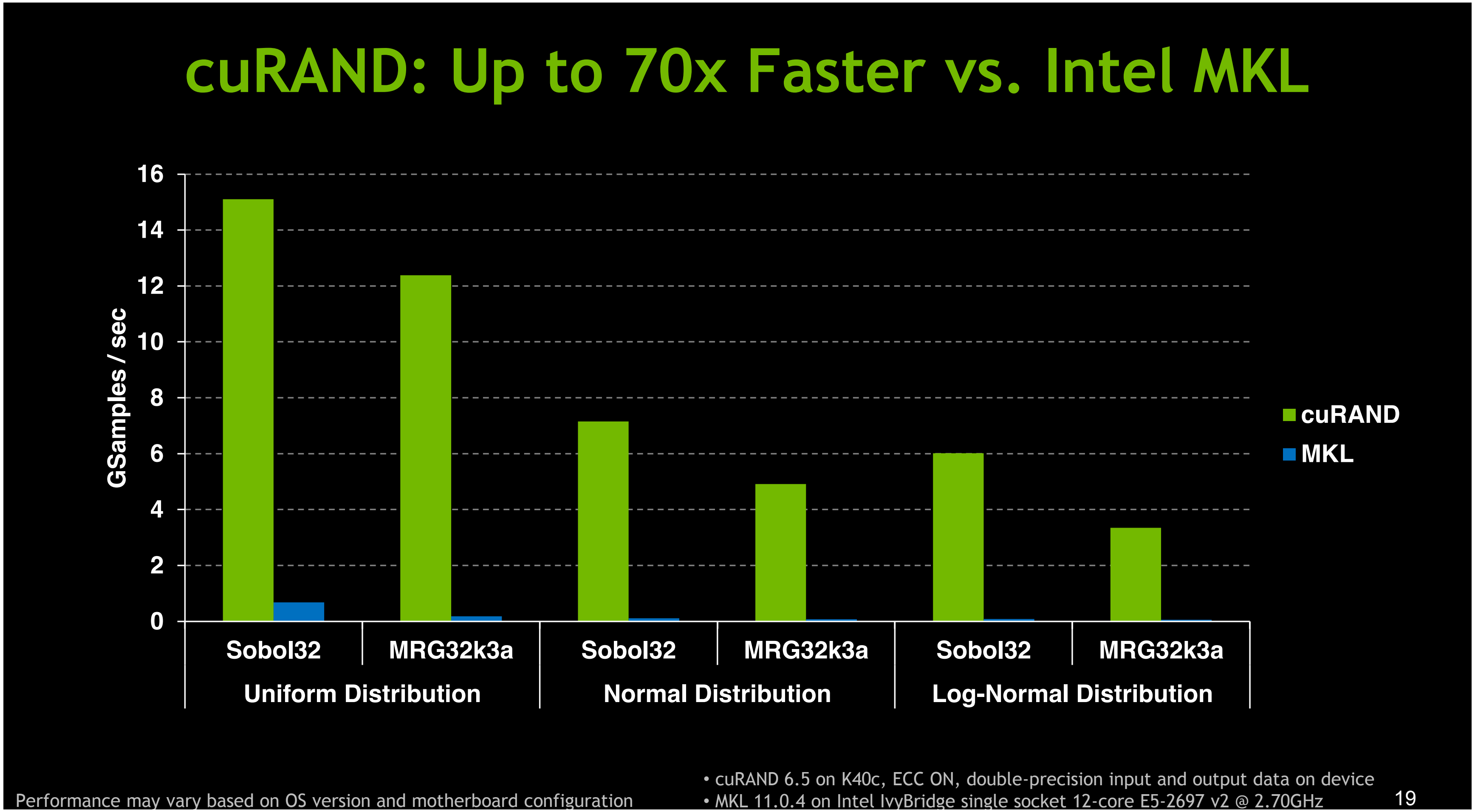
- RBM:
  - Do something: MCMC, RNG
  - Updating weights: minibatch, GEMM



- CNN:
  - Convolutional layers(90-95%): cuDNN, FFT(cuFFT,fbFFT)
  - Fully connected layers(5-10%)

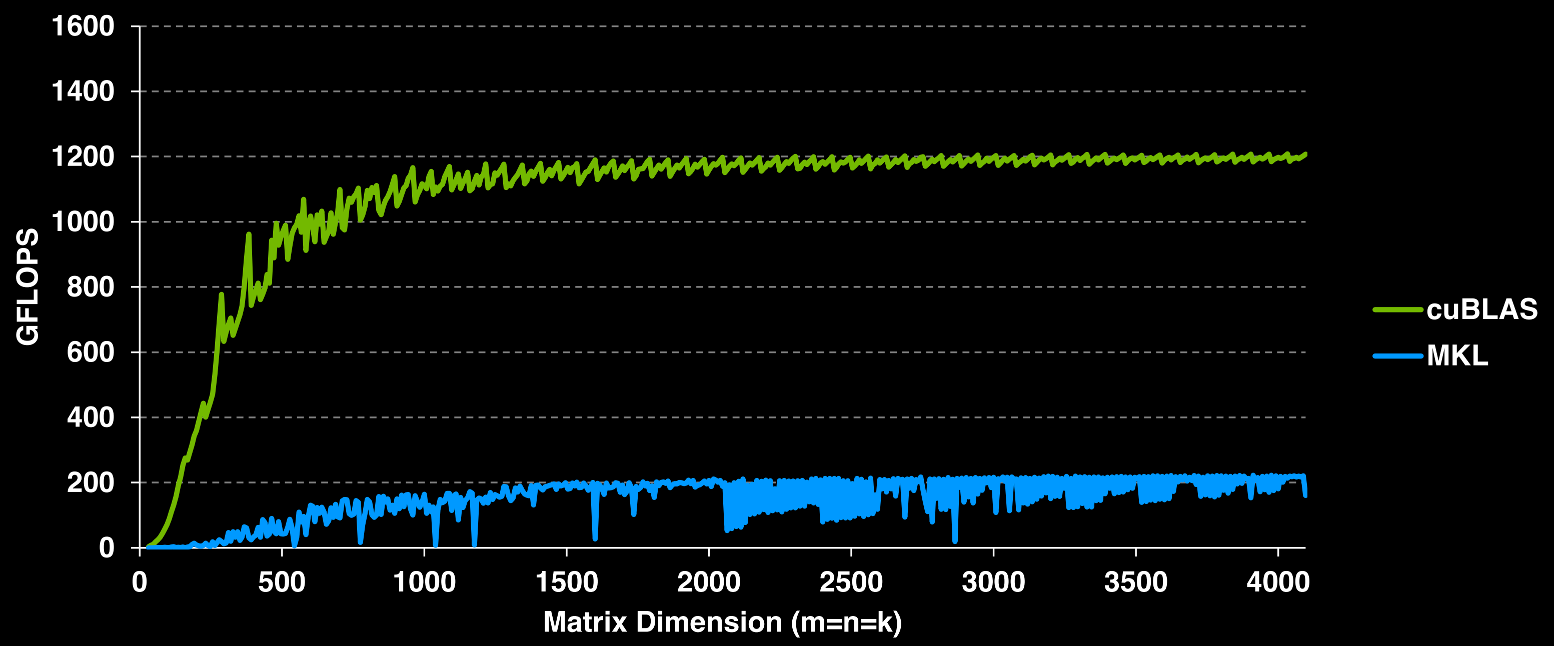


Why using GPU?



Why using GPU?

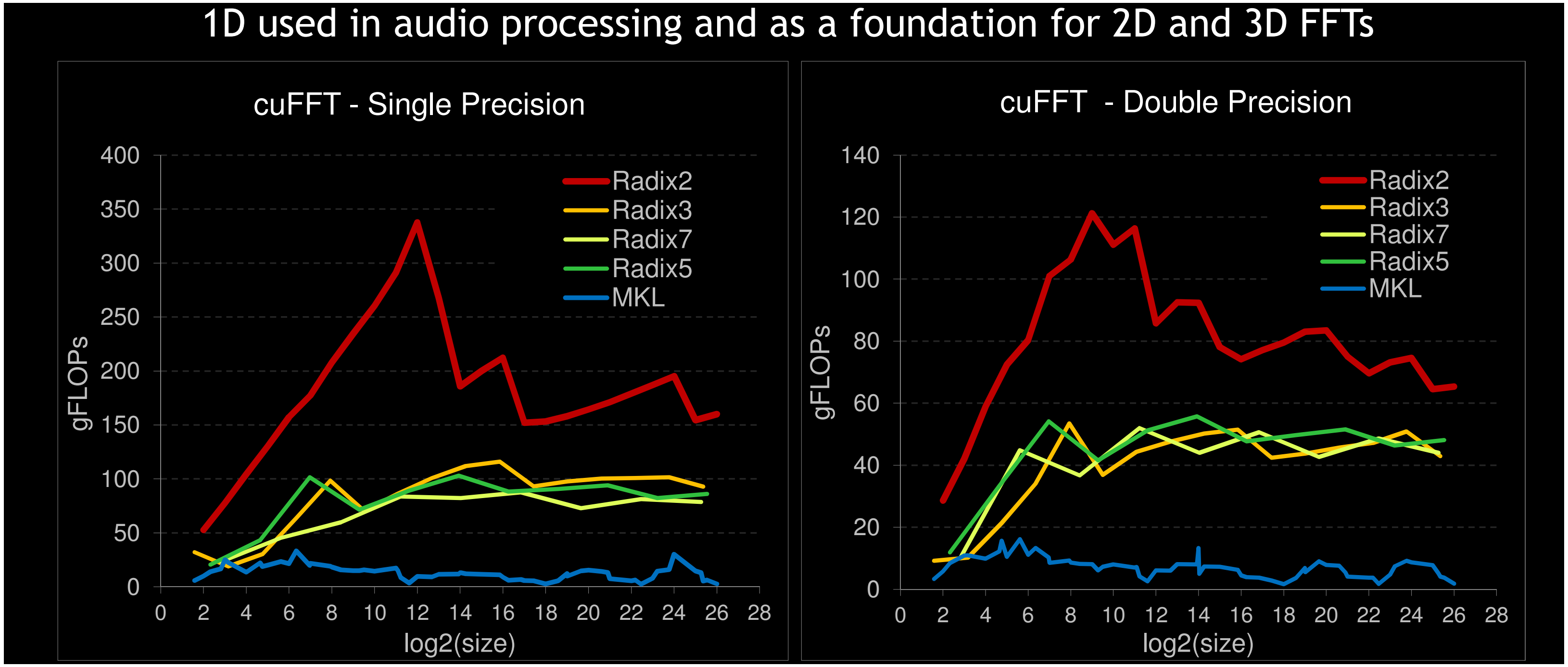
cuBLAS: ZGEMM 6x Faster than MKL



Performance may vary based on OS version and motherboard configuration

- cuBLAS 6.5 on K40m, ECC ON, input and output data on device
- MKL 11.0.4 on Intel IvyBridge single socket 12-core E5-2697 v2 @ 2.70GHz

Why using GPU?

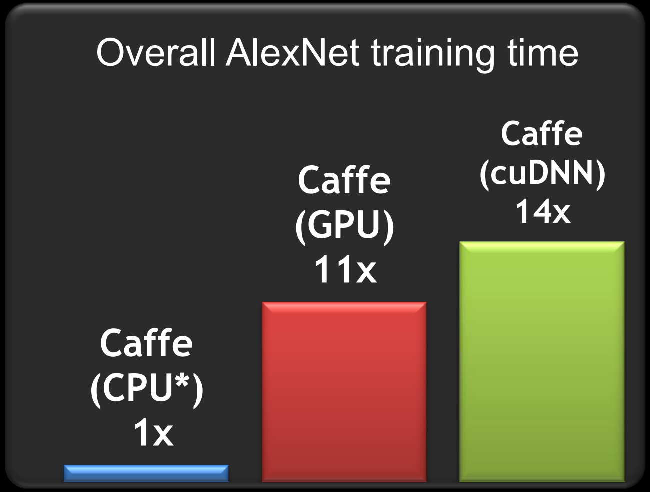


Why using GPU?

Using Caffe with cuDNN

- Accelerate Caffe layer types by 1.2 - 3x
  Example: AlexNet Layer 2 forward:
  1.9x faster convolution, 2.7x faster pooling

- Integrated into Caffe dev branch today!
  (targeting official release with Caffe 1.0)



Baseline Caffe compared to Caffe accelerated by cuDNN on K40

*CPU is 24 core E5-2697v2 @ 2.4GHz Intel MKL 11.1.3

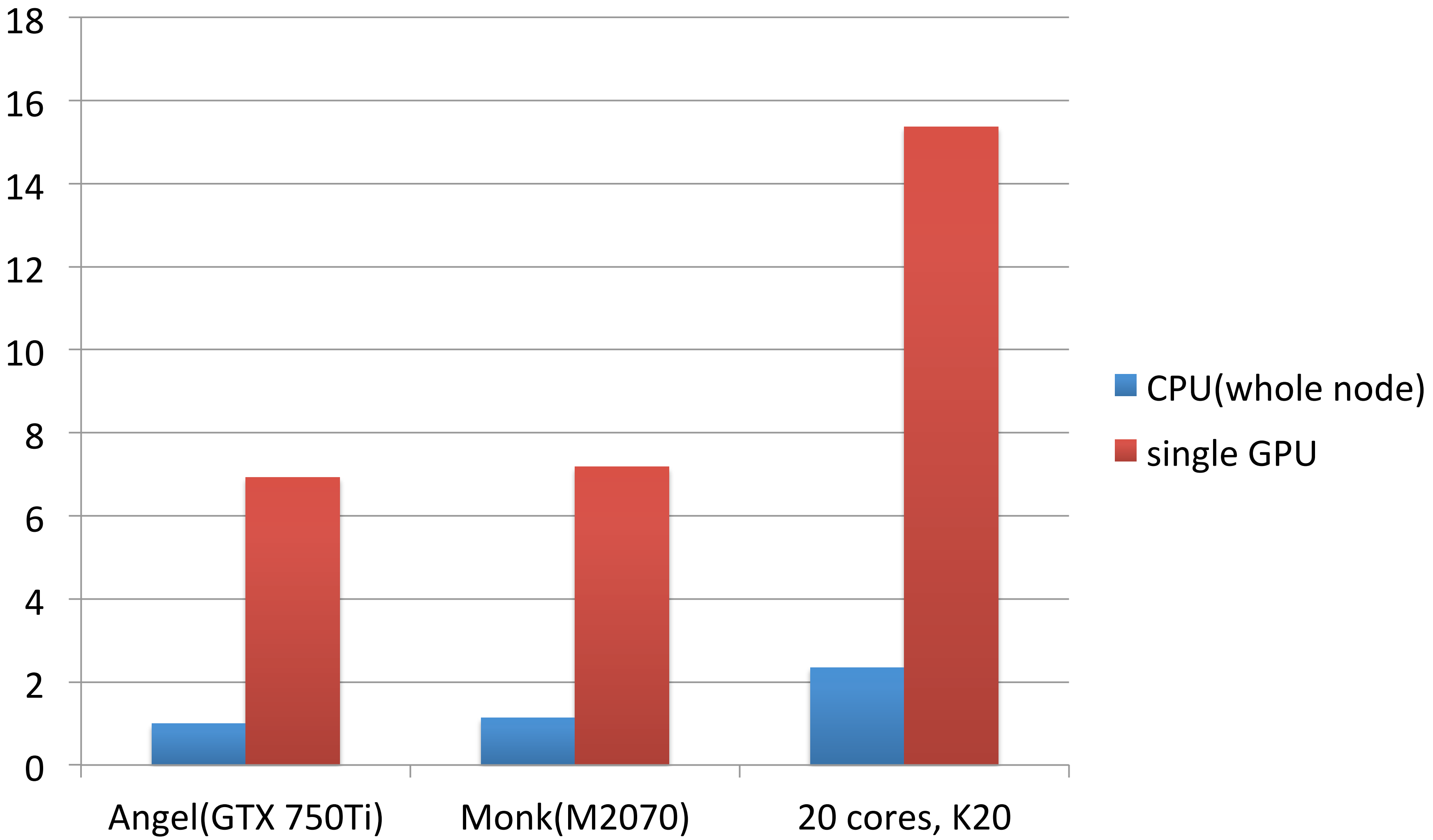
Deep Learning tools

- Theano:
  - a Python library that allows you to define, optimize, and evaluate mathematical expressions involving multi-dimensional arrays efficiently
  - transparent use of a GPU(defined in ~/.theanorc)
  - efficient symbolic differentiation
  - speed and stability optimizations
- Theano demo and benchmark:
  - Deep Generative Stochastic Networks(GSN)

Running Theano on SHARCNET

1. Load python module:
   - On monk, module load python/intel/2.7.8
2. Export PYTHONPATH for other package
   - export PYTHONPATH=/yourpath/python_packages/lib/python2.7/site-packages:$PYTHONPATH
3. Edit ".theanorc" under /home/username
   - Add "device = gpu" under [global]
4. Run/sqsub python run_gsn.py

Theano GPU Speedup



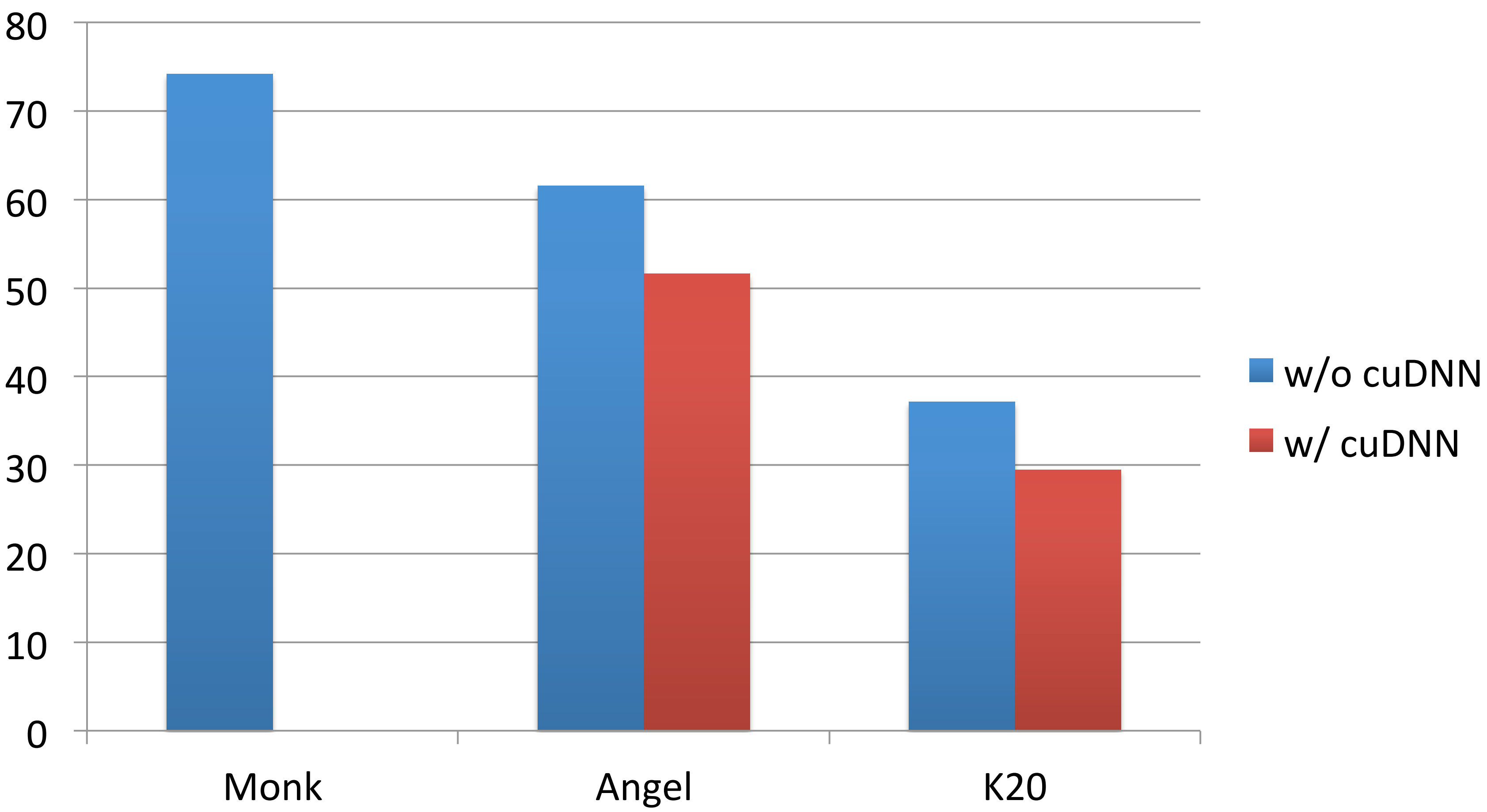
Deep Learning tools

- Caffe:
  - A deep learning framework developed with cleanliness, readability, and speed in mind.
  - Fast GPU implementation with cuDNN
  - Designing your CNN without coding
- Caffe demo and benchmark:
  - Training CaffeNet/AlexNet on ImageNet!

Running Caffe on SHARCNET

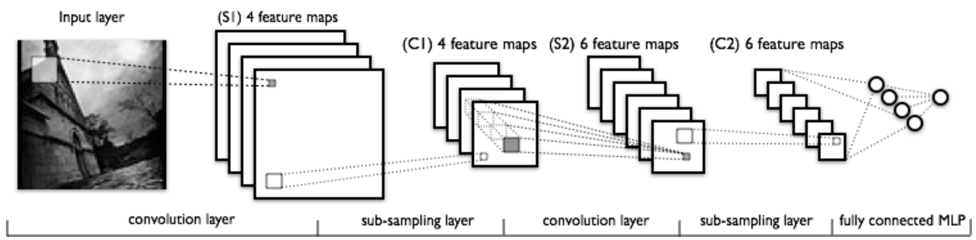
1. Load gcc module:
   - Unload intel mkl openmpi and then load gcc/4.8.2
2. Export PATH and LD_LIBRARY_PATH
   - Monk use cuda 6(modified code)
   - Angel use cuda 6.5 with cuDNN
   - Dependencies: /work/feimao/software_installs/
3. Create *LEVELDB* file from images
   - LMDB is default but doesn't work on SHARCNET
4. Modify train_val.prototxt with leveldb read file, batch size, etc.
5. Modify solver.prototxt for lr, momentum ,etc.
6. Run/sqsub ./build/tools/caffe train --solver=…

CaffeNet training time(s)

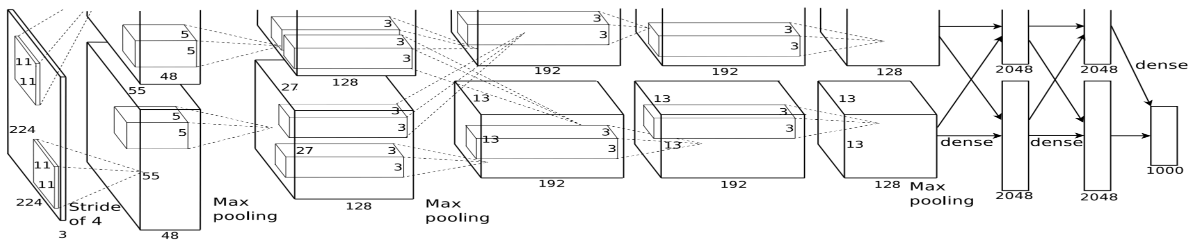


Training on ImageNet with 128 batch size, 40 tiers = 128*40=5120 images

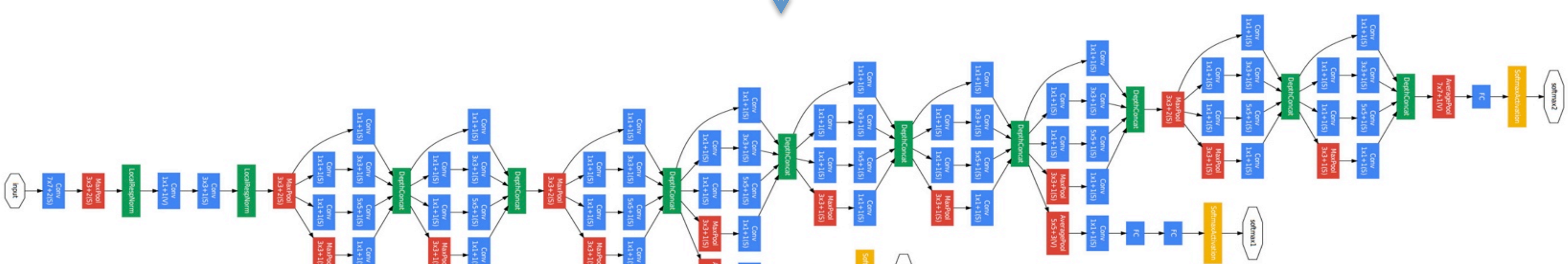
Why go deeper and larger



LeNet-5:
60k Handwritten digits



AlexNet:
1.2m ImageNet(15m pretrain), 7 CNNs, 15.3% top-5 error



GoogLeNet: 6.67% top-5 error

Going deeper is not easy!

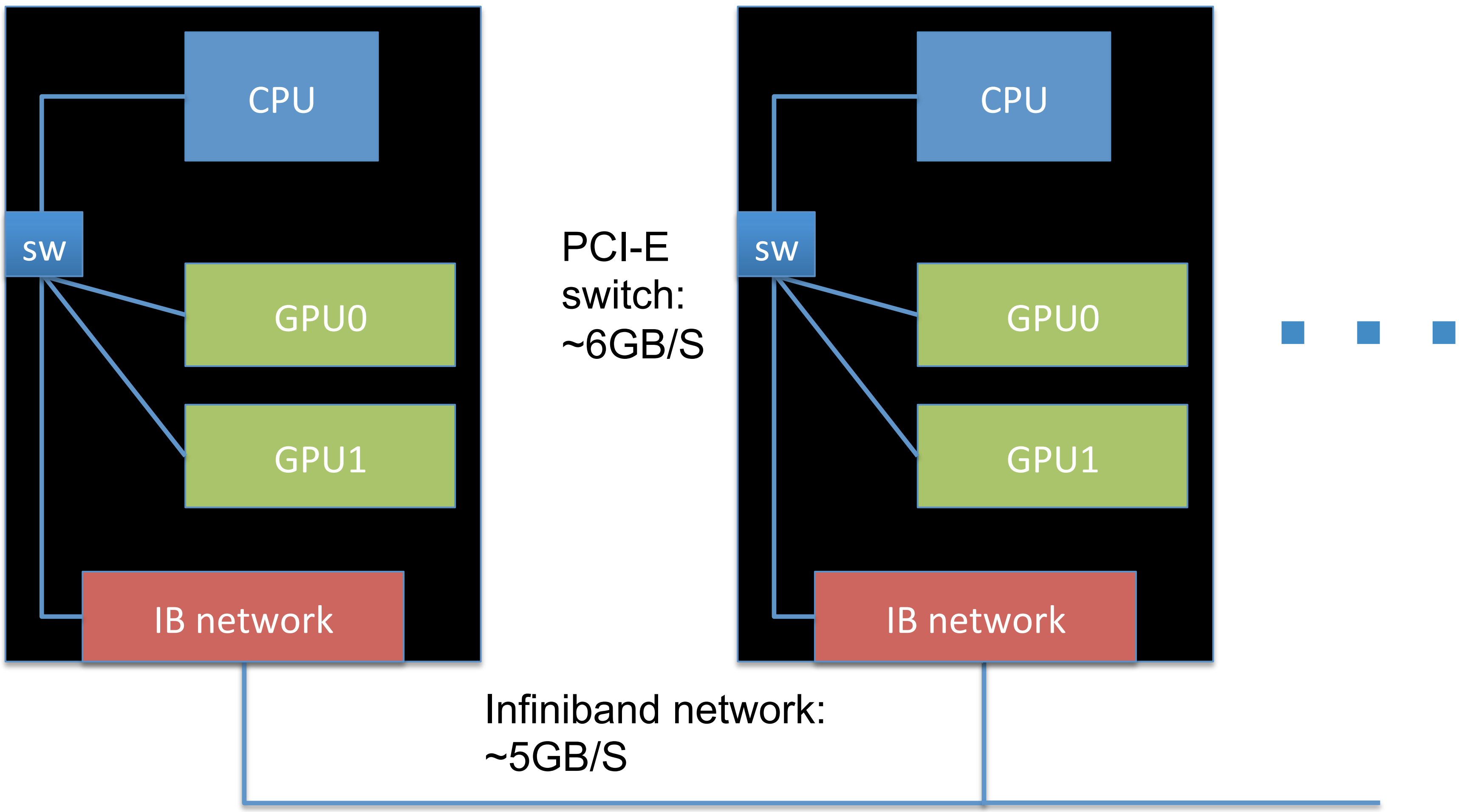
- Theano and Caffe support single GPU ONLY!
- Long time to train on big dataset:
  - AlexNet: On a K40 machine, every 20 iterations(5120 images) costs 26.5 seconds to run! 160 hours for 90 epoch!
  - GoogLeNet: K40, 5120 images takes 67.5 seconds! More than a month for 250 epoch!
- How to train huge networks in reasonable time?

GPU cluster is the cure!

- In 2012, Google used a CPU cluster of 1000 nodes(16000 cores) to train a network with 1.8B parameters.
- In 2013, 16-node GPU cluster(COTS HPC, 64 gpus) can train a model with 11.2B parameters!
- In 2015, Baidu used a 36-node GPU cluster (144 gpus) to train a network for ImageNet with larger image size(512x512) and more cropped samples. Top-5 error: 5.98%

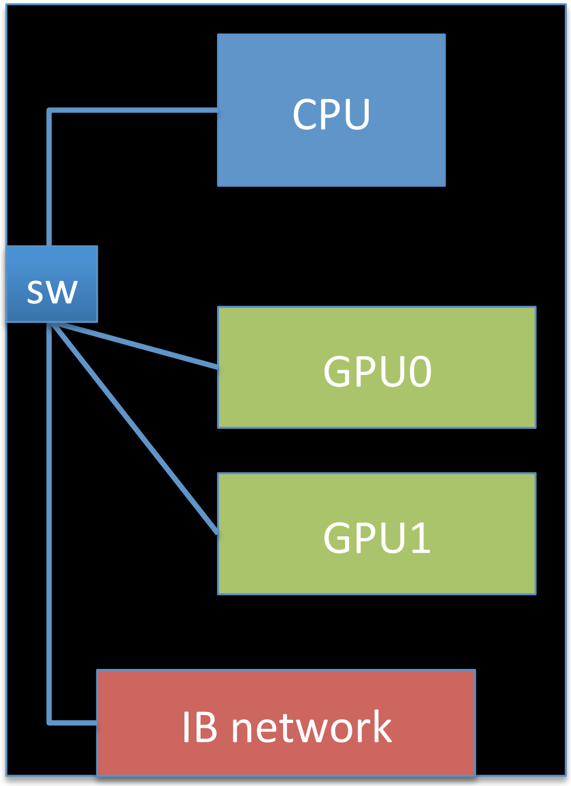
Developing on GPU cluster

- Hardware topology: (Monk)



Developing on GPU cluster

- Intra-node comm (GPUDirect P2P)



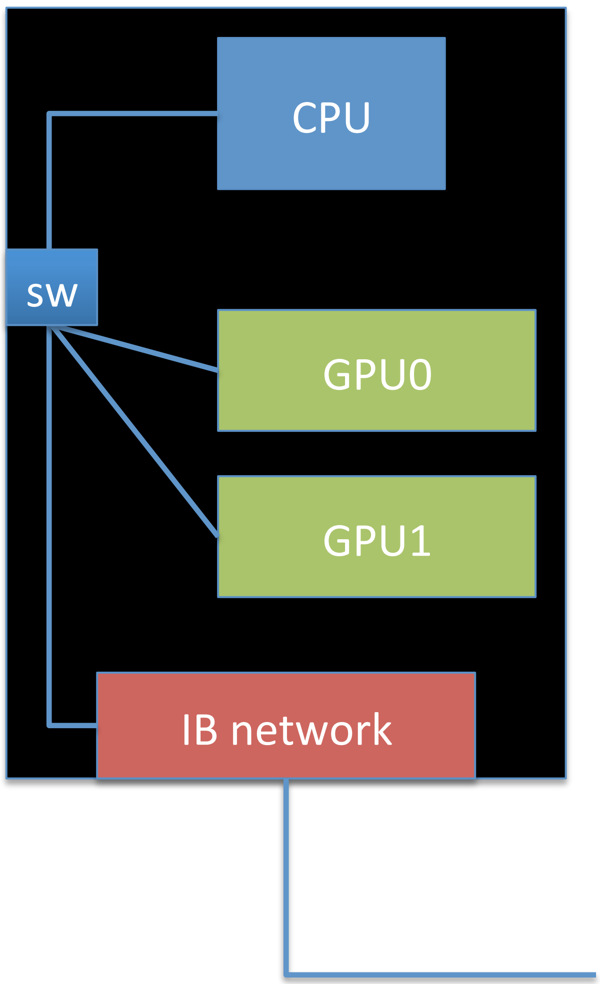
- w/o P2P: data go to CPU memory
  - CudaSetDevice(0)
  - CudaMalloc(d_0)
  - CudaMemcpy(d_0 to h_0)
  - CudaSetDevice(1)
  - CudaMalloc(d_1)
  - CudaMemcpy(h_0 to d_1)
- w/ P2P: data go through PCI-E bus
  - CudaSetDevice(0)
  - CudaMalloc(d_0)
  - CudaSetDevice(1)
  - CudaMalloc(d_1)
  - CudaMemcpyPeer(d_0 to d_1)

Developing on GPU cluster

- Multi-GPU implementation of Theano:
  - Parallel data loading
  - Data parallelism of AlexNet
  - Using PyCUDA with GPUDirect P2P support
  - ~1.7x speed-up with 2 GPUs
  - https://github.com/uoguelph-mlrg/theano_alexnet

Developing on GPU cluster

- Inter-node comm (CUDA-aware MPI)



- w/o cuda-aware MPI: data go to CPU memory and then IB network
    - CudaMalloc(d_0 on proc_0)
    - CudaMalloc(d_1 on proc_1)
    - CudaMemcpy(d_0 to h_0)
    - MPI_Send(from h_0 to h_1)
    - CudaMemcpy(h_1 to d_1)
- w/ P2P: GPU data go to IB network through PCI-E bus
    - CudaMalloc(d_0 on proc_0)
    - CudaMalloc(d_1 on proc_11)
    - MPI_Send(from d_0 to d_1)

Conclusion:

Go deeper and deeper and deeper… on GPU cluster!