# Introduction to SDSC Comet

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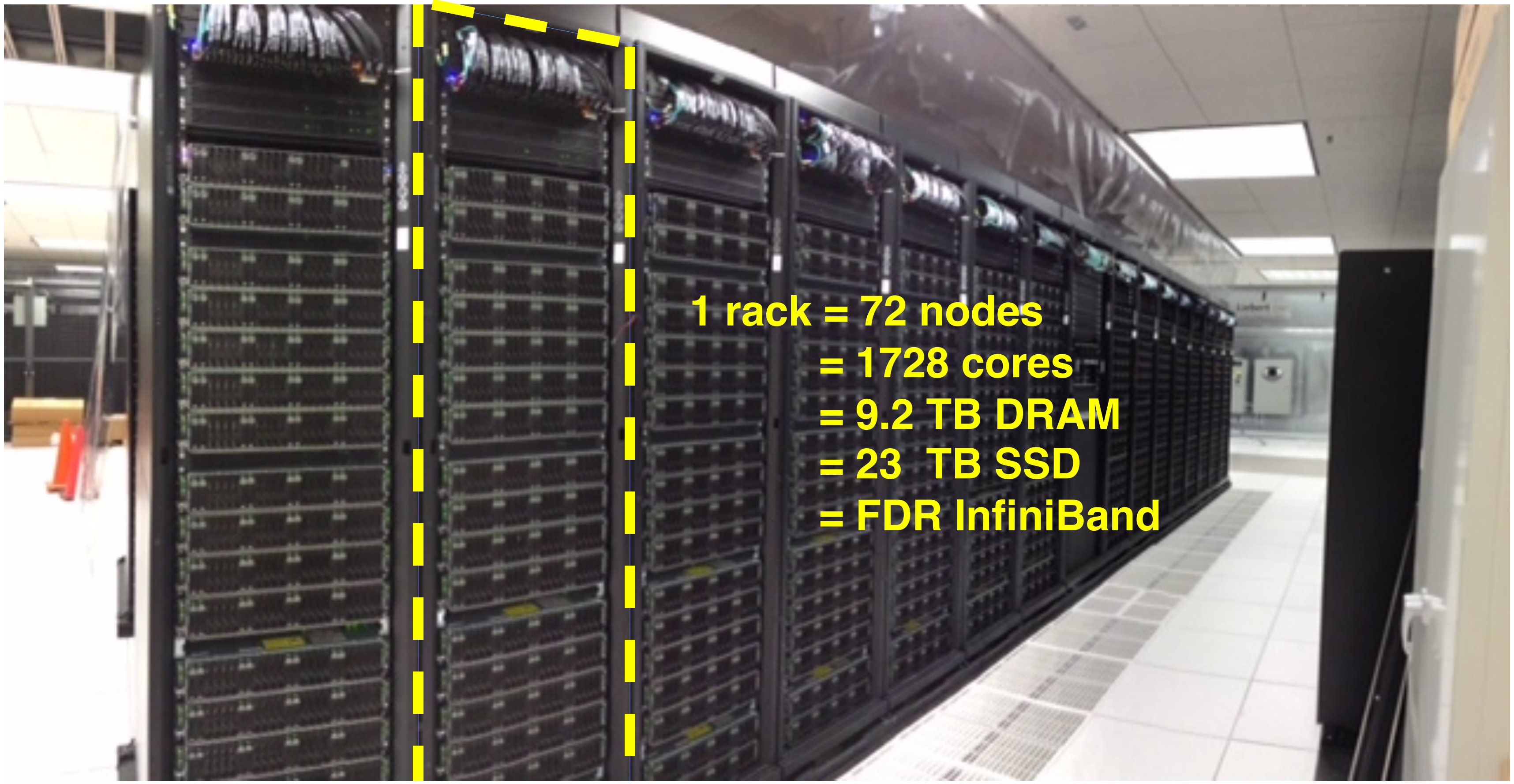
## Comet
## “HPC for the long tail of science”

**iPhone panorama photograph of 1 of 2 server rows**

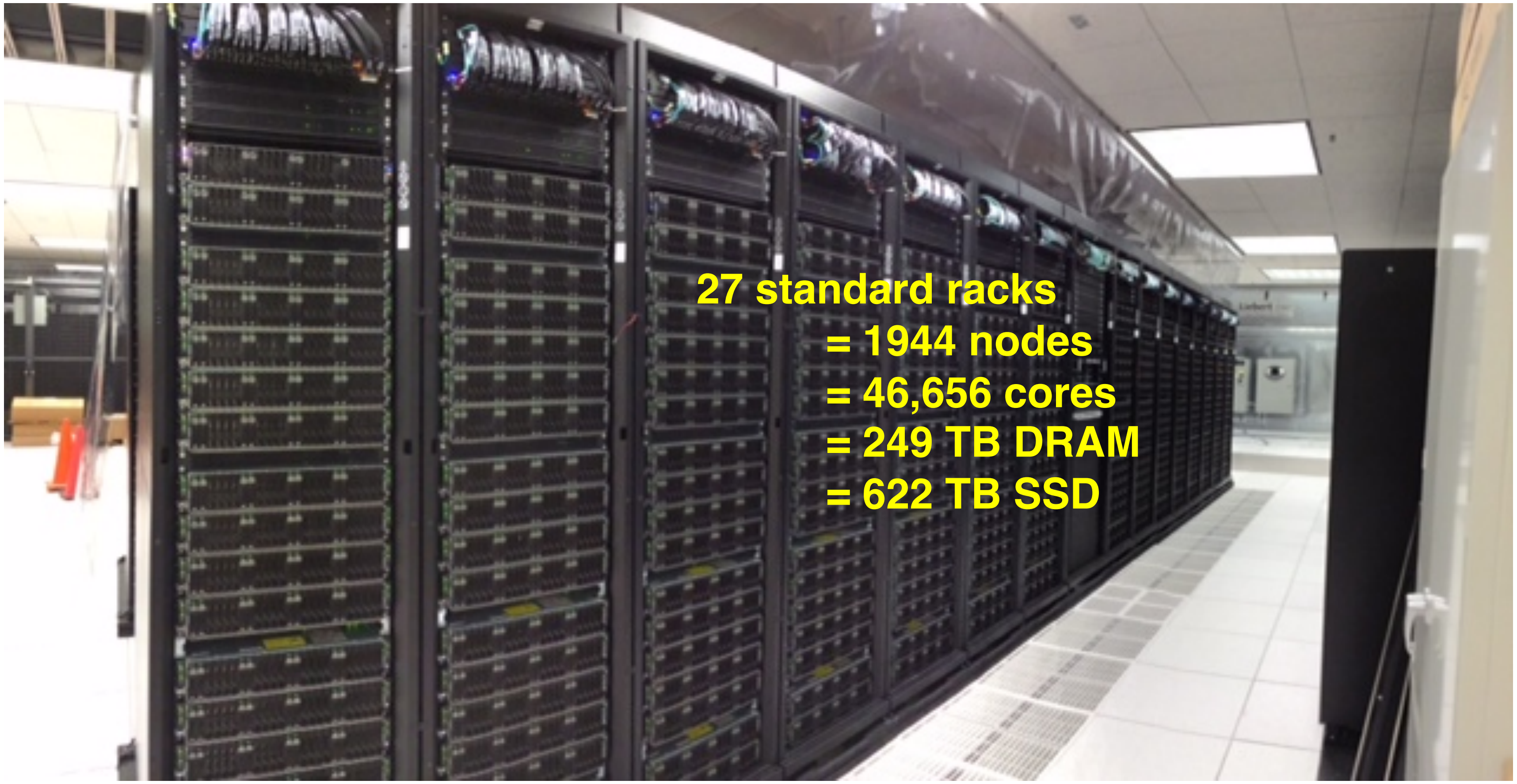
# Comet: System Characteristics

- **Total peak flops ~2.1 PF**
- **Dell primary integrator**
  - Intel Haswell processors w/ AVX2
  - Mellanox FDR InfiniBand
- **1,944 standard compute nodes (46,656 cores)**
  - Dual CPUs, each 12-core, 2.5 GHz
  - 128 GB DDR4 2133 MHz DRAM
  - 2*160GB GB SSDs (local disk)
- **72 GPU nodes**
  - 36 nodes same as standard nodes *plus* Two NVIDIA K80 cards, each with dual Kepler3 GPUs
  - 36 nodes, with 4 P100 GPUs per node
- **4 large-memory nodes**
  - 1.5 TB DDR4 1866 MHz DRAM
  - Four Haswell processors/node
  - 64 cores/node
- **Hybrid fat-tree topology**
  - FDR (56 Gbps) InfiniBand
  - Rack-level (72 nodes, 1,728 cores) full bisection bandwidth
  - 4:1 oversubscription cross-rack
- **Performance Storage (Aeon)**
  - 7.6 PB, 200 GB/s; Lustre
  - Scratch & Persistent Storage segments
- **Durable Storage  (Aeon)**
  - 6 PB, 100 GB/s; Lustre
  - Automatic backups of critical data
- **Home directory storage**
- **Gateway hosting nodes**
- **Virtual image repository**
- **100 Gbps external connectivity to Internet2 & ESNet**

# ~67 TF supercomputer in a rack

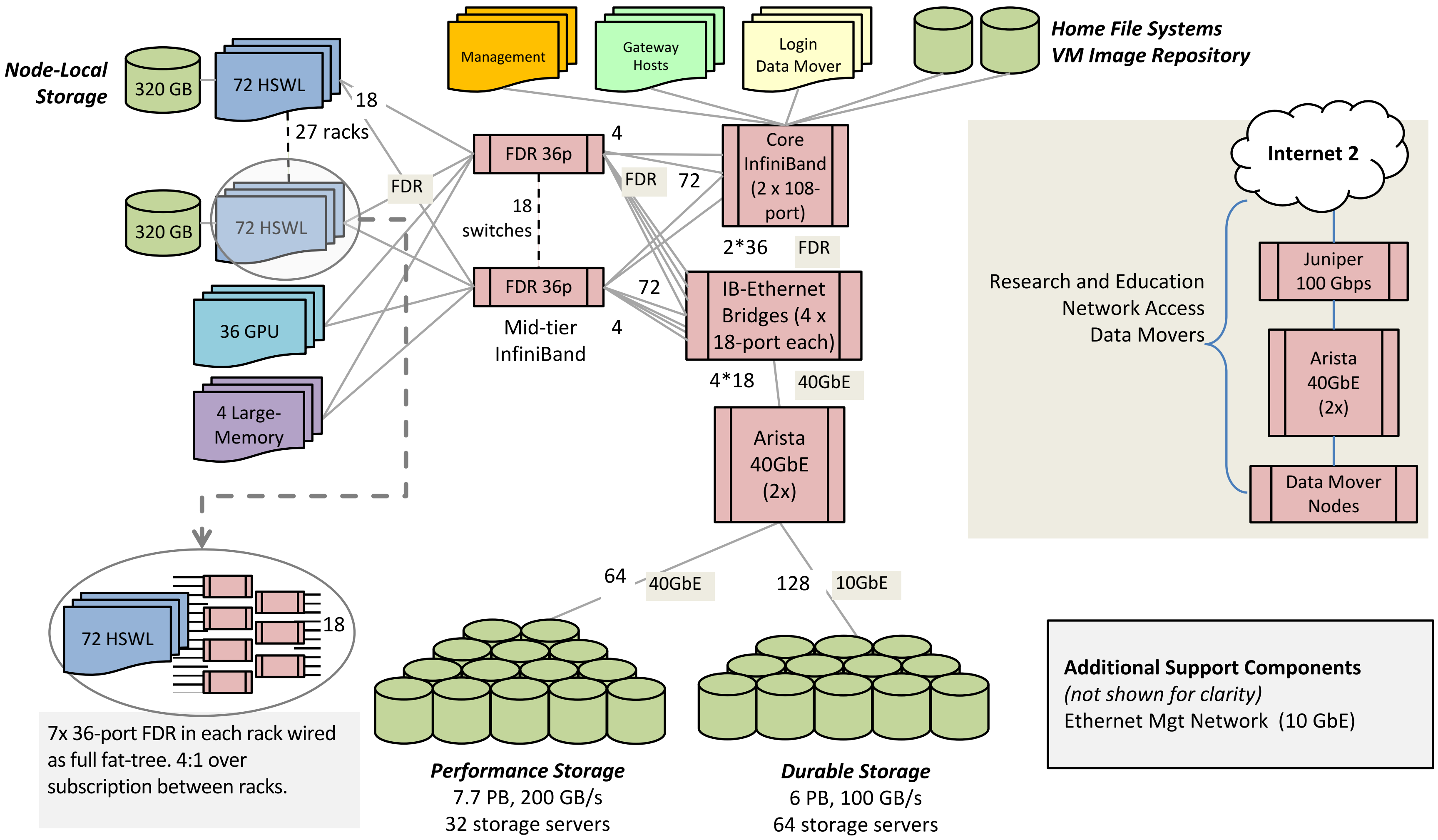


## And 27 single-rack supercomputers



# Comet Network Architecture

## InfiniBand compute, Ethernet Storage



7x 36-port FDR in each rack wired as full fat-tree. 4:1 over subscription between racks.

**Additional Support Components**
*(not shown for clarity)*
Ethernet Mgt Network (10 GbE)

## Getting Started

- **System Access – Logging in**
  - Linux/Mac – Use available ssh clients.
  - ssh clients for windows – Putty, Cygwin
    - http://www.chiark.greenend.org.uk/~sgtatham/putty/
  - Login hosts for the SDSC Comet:
    - comet.sdsc.edu

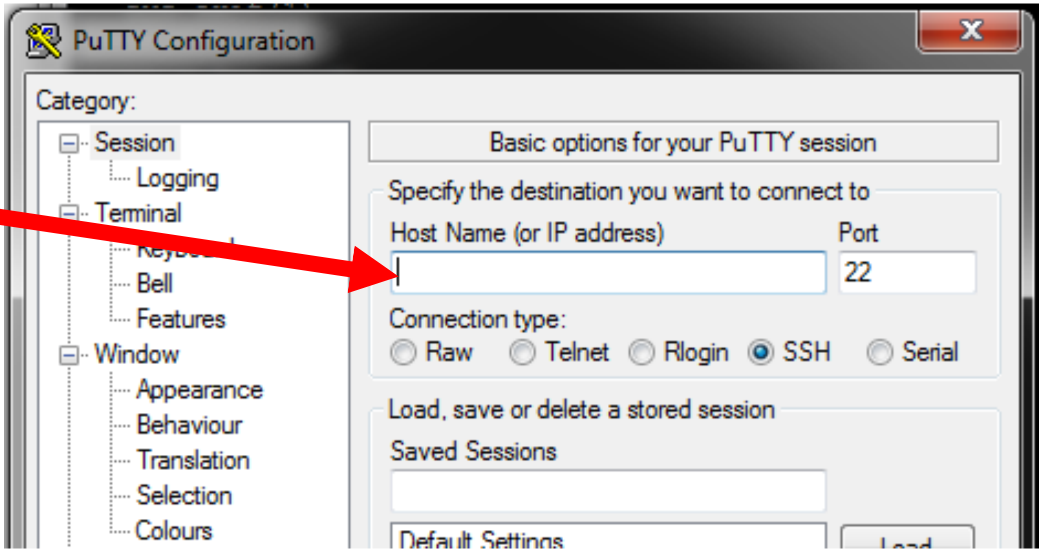
## Logging into Comet

**Mac/Linux:**

```
ssh username@comet.sdsc.edu
```

**Windows (PuTTY):**

comet.sdsc.edu



Host Name (or IP address):
Port: 22
Connection type: Raw Telnet Rlogin [✓ SSH] Serial

# Comet: Filesystems

- **Lustre filesystems – Good for scalable large block I/O**
  - Accessible from all compute and GPU nodes.
  - /oasis/scratch/comet - 2.5PB, peak performance: 100GB/s. Good location for storing large scale scratch data during a job.
  - /oasis/projects/nsf - 2.5PB, peak performance: 100 GB/s. Long term storage.
  - ***Not good for lots of small files or small block I/O***.
- **SSD filesystems**
  - /scratch local to each native compute node – 210GB on regular compute nodes, 285GB on GPU, large memory nodes, 1.4TB on selected compute nodes.
  - SSD location is good for writing small files and temporary scratch files. Purged at the end of a job.
- **Home directories (/home/$USER)**
  - Source trees, binaries, and small input files.
  - ***Not good for large scale I/O.***

# Comet: System Environment

- **Modules used to manage environment for users.**
- **Default environment:**

```
$ module li
Currently Loaded Modulefiles:
  1) intel/2013_sp1.2.144   2) mvapich2_ib/2.1       3) gnutools/2.69
```

- **Listing available modules:**

```
$ module av
------------------------- /opt/modulefiles/mpi/.intel -------------------------
intelmpi/2016.3.210(default) mvapich2_ib/2.1(default)
mvapich2_gdr/2.1(default)    openmpi_ib/1.8.4(default)
mvapich2_gdr/2.2
--------------------- /opt/modulefiles/applications/.intel ---------------------
atlas/3.10.2(default)     lapack/3.6.0(default)     scalapack/2.0.2(default)
boost/1.55.0(default)     mxml/2.9(default)         slepc/3.6.2(default)
…
…
```

## Comet: System Environment

- **Loading modules:**

```
$ module load fftw/3.3.4
$ module li
Currently Loaded Modulefiles:
  1) intel/2013_sp1.2.144   3) gnutools/2.69
  2) mvapich2_ib/2.1        4) fftw/3.3.4
```

- **See what a module does:**

```
$ module show fftw/3.3.4
-------------------------------------------------------------------
/opt/modulefiles/applications/.intel/fftw/3.3.4:
module-whatis fftw
module-whatis Version: 3.3.4
module-whatis Description: fftw
module-whatis Compiler: intel
module-whatis MPI Flavors: mvapich2_ib openmpi_ib
setenv FFTWHOME /opt/fftw/3.3.4/intel/mvapich2_ib
prepend-path PATH /opt/fftw/3.3.4/intel/mvapich2_ib/bin
prepend-path LD_LIBRARY_PATH /opt/fftw/3.3.4/intel/mvapich2_ib/lib
prepend-path LIBPATH /opt/fftw/3.3.4/intel/mvapich2_ib/lib
-------------------------------------------------------------------
```

## Comet: System Environment

```
$ echo $PATH
/opt/fftw/3.3.4/intel/mvapich2_ib/bin:/share/apps/compute/bbftp/bin:/home/mahidhar/pdsh/bin:/opt/gnu/gcc/bin:/opt/gnu/bin:/opt/mvapich2/intel/ib/bin:/opt/intel/composer_xe_2013_sp1.2.144/bin/intel64:/opt/intel/composer_xe_2013_sp1.2.144/mpirt/bin/intel64:/opt/intel/composer_xe_2013_sp1.2.144/debugger/gdb/intel64_mic/bin:/usr/lib64/qt-3.3/bin:/usr/local/bin:/bin:/usr/bin:/usr/local/sbin:/usr/sbin:/sbin:/opt/ibutils/bin:/usr/java/latest/bin:/opt/pdsh/bin:/opt/rocks/bin:/opt/rocks/sbin:/opt/sdsc/bin:/opt/sdsc/sbin:/home/mahidhar/bin

$ echo $FFTWHOME
/opt/fftw/3.3.4/intel/mvapich2_ib
```

## Parallel Programming

- **Comet supports MPI, OpenMP, and Pthreads for parallel programming. Hybrid modes are possible.**
- **GPU nodes support CUDA, OpenACC.**
- **MPI**
  - Default: mvapich2_ib/2.1
  - Other options: openmpi_ib/1.8.4 (and 1.10.2), Intel MPI
  - mvapich2_gdr: GPU direct enabled version
- **OpenMP:** All compilers (GNU, Intel, PGI) have OpenMP flags.
- Default Intel Compiler: **intel/2013_sp1.2.144;** *Versions 2015.2.164 and 2016.3.210 available.*

## Example Files for Class

- **Copy directory:**

```
cp -r /share/apps/examples/UCSB2018 /home/$USER
```

- **Make sure you have all the files:**

```
$ ls /home/$USER/UCSB2018
CUDA HYBRID       LOCALSCRATCH2  MPI     pytorch  TensorFlow
HADOOP LOCALSCRATCH  MKL     OPENMP  SPARK
```

# Running Jobs on Comet

- **Important note: Do not run on the login nodes - even for simple tests.**
- **All runs must be via the Slurm scheduling infrastructure.**
  - Interactive Jobs: Use **srun** command:

```
srun --pty --nodes=1 --ntasks-per-node=24 -p debug -t 00:30:00 --wait 0 /bin/bash
```

  - Batch Jobs: Submit batch scripts from the login nodes. Can choose:
    - Partition (details on upcoming slide)
    - Time limit for the run (maximum of 48 hours)
    - Number of nodes, tasks per node
    - Memory requirements (if any)
    - Job name, output file location
    - Email info, configuration

# Slurm Partitions

| Queue Name | Max Walltime | Max Nodes | Comments |
|---|---|---|---|
| compute | 48 hrs | 72 | Used for access to regular compute nodes |
| gpu | 48 hrs | 4 | Used for access to the GPU nodes |
| gpu-shared | 48 hrs | 1 | Used for shared access to a partial GPU node |
| shared | 48 hrs | 1 | Single-node jobs using fewer than 24 cores |
| large-shared | 48 hrs | 1 | Single-node jobs using large memory up to 1.45 TB |
| debug | 30 mins | 2 | Used for access to debug nodes |

- **Specified using -p option in batch script. For example:**

```
#SBATCH -p gpu
```

## Slurm Commands

- **Submit jobs using the sbatch command:**

```
$ sbatch Localscratch-slurm.sb
Submitted batch job 8718049
```

- **Check job status using the squeue command:**

```
$ squeue -u $USER
    JOBID PARTITION     NAME     USER  ST       TIME  NODES NODELIST(REASON)
  8718049   compute localscr mahidhar  PD       0:00      1          (Priority)
```

- **Once the job is running:**

```
$ squeue -u $USER
    JOBID PARTITION     NAME     USER  ST       TIME  NODES NODELIST(REASON)
  8718064     debug localscr mahidhar   R       0:02      1       comet-14-01
```

# Comet Compute Nodes

## 2-Socket (Total 24 cores) Intel Haswell Processors

Hands On Examples using:

(1) MPI

(2) OpenMP

(3) HYBRID

(4) Local scratch

(5) MKL Example

# Comet – Compiling/Running Jobs

- **Copy and change to directory (assuming you already copied the PHYS244 directory):**

```
cd /home/$USER/UCSB2018/MPI
```

- **Verify modules loaded:**

```
module list
Currently Loaded Modulefiles:
  1) intel/2013_sp1.2.144   2) mvapich2_ib/2.1        3) gnutools/2.69
```

- **Compile the MPI hello world code:**

```
mpif90 -o hello_mpi hello_mpi.f90
```

- **Verify executable has been created:**

```
ls -lt hello_mpi
-rwxr-xr-x 1 mahidhar sdsc 721912 Mar 25 14:53 hello_mpi
```

- **Submit job from IBRUN directory:**

```
cd /home/$USER/UCSB2018/MPI/IBRUN
sbatch hellompi-slurm.sb
```

## Comet: Hello World on compute nodes

The submit script is hellompi-slurm.sb:

```
#!/bin/bash
#SBATCH --job-name="hellompi"
#SBATCH --output="hellompi.%j.%N.out"
#SBATCH --partition=compute
#SBATCH --nodes=2
#SBATCH --ntasks-per-node=24
#SBATCH --export=ALL
#SBATCH -t 01:30:00

#This job runs with 2 nodes, 24 cores per node for a total of 48 cores.
#ibrun in verbose mode will give binding detail

ibrun -v ./hello_mpi
```

## Comet: Hello World on compute nodes

```
IBRUN: Command is ../hello_mpi
IBRUN: Command is /share/apps/examples/MPI/hello_mpi
…
…
IBRUN: MPI binding policy: compact/core for 1 threads per rank (12 cores per socket)
IBRUN: Adding MV2_CPU_BINDING_LEVEL=core to the environment
IBRUN: Adding MV2_ENABLE_AFFINITY=1 to the environment
IBRUN: Adding MV2_DEFAULT_TIME_OUT=23 to the environment
IBRUN: Adding MV2_CPU_BINDING_POLICY=bunch to the environment
…
…
IBRUN: Added 8 new environment variables to the execution environment
IBRUN: Command string is [mpirun_rsh -np 48 -hostfile /tmp/rssSvauaJA -export /s
hare/apps/examples/MPI/hello_mpi]
 node          18 : Hello world
 node          13 : Hello world
 node           2  : Hello world
 node          10 : Hello world
```

## Compiling OpenMP Example

- **Change to the examples directory:**

```
cd /home/$USER/UCSB2018/OPENMP
```

- **Compile using –openmp flag:**

```
ifort -o hello_openmp -openmp hello_openmp.f90
```

- **Verify executable was created:**

```
[mahidhar@comet-08-11 OPENMP]$ ls -lt hello_openmp
-rwxr-xr-x 1 mahidhar sdsc 750648 Mar 25 15:00 hello_openmp
```

# OpenMP job script

```
#!/bin/bash
#SBATCH --job-name="hell_openmp"
#SBATCH --output="hello_openmp.%j.%N.out"
#SBATCH --partition=compute
#SBATCH --nodes=1
#SBATCH --ntasks-per-node=24
#SBATCH --export=ALL
#SBATCH -t 01:30:00

#SET the number of openmp threads
export OMP_NUM_THREADS=24

#Run the job using mpirun_rsh
./hello_openmp
```

## Output from OpenMP Job

```
$ more hello_openmp.out
 HELLO FROM THREAD NUMBER =           7
 HELLO FROM THREAD NUMBER =           6
 HELLO FROM THREAD NUMBER =           9
 HELLO FROM THREAD NUMBER =           8
 HELLO FROM THREAD NUMBER =           5
 HELLO FROM THREAD NUMBER =           4
 HELLO FROM THREAD NUMBER =           0
 HELLO FROM THREAD NUMBER =          12
 HELLO FROM THREAD NUMBER =          14
 HELLO FROM THREAD NUMBER =           3
 HELLO FROM THREAD NUMBER =          13
 HELLO FROM THREAD NUMBER =          10
 HELLO FROM THREAD NUMBER =          11
 HELLO FROM THREAD NUMBER =           2
 HELLO FROM THREAD NUMBER =           1
 HELLO FROM THREAD NUMBER =          15
```

## Running Hybrid (MPI + OpenMP) Jobs

- Several HPC codes use a hybrid MPI, OpenMP approach.
- “ibrun” wrapper developed to handle such hybrid use cases. Automatically senses the MPI build (mvapich2, openmpi) and binds tasks correctly.
- “ibrun –help” gives detailed usage info.
- hello_hybrid.c is a sample code, and hello_hybrid.cmd shows “ibrun” usage.

## hello_hybrid.cmd

```
#!/bin/bash
#SBATCH --job-name="hellohybrid"
#SBATCH --output="hellohybrid.%j.%N.out"
#SBATCH --partition=compute
#SBATCH --nodes=2
#SBATCH --ntasks-per-node=24
#SBATCH --export=ALL
#SBATCH -t 01:30:00

#This job runs with 2 nodes, 24 cores per node for a total of 48 cores.

# We use 8 MPI tasks and 6 OpenMP threads per MPI task
export OMP_NUM_THREADS=6
ibrun --npernode 4 ./hello_hybrid
```

## Hybrid Code Output

```
[etrain61@comet-ln3 HYBRID]$ more hellohybrid.8557716.comet-14-01.out
Hello from thread 0 out of 6 from process 2 out of 8 on comet-14-01.local
Hello from thread 3 out of 6 from process 2 out of 8 on comet-14-01.local
Hello from thread 4 out of 6 from process 2 out of 8 on comet-14-01.local
Hello from thread 5 out of 6 from process 2 out of 8 on comet-14-01.local
Hello from thread 0 out of 6 from process 3 out of 8 on comet-14-01.local
Hello from thread 2 out of 6 from process 2 out of 8 on comet-14-01.local
Hello from thread 1 out of 6 from process 3 out of 8 on comet-14-01.local
Hello from thread 2 out of 6 from process 3 out of 8 on comet-14-01.local
…
…
Hello from thread 4 out of 6 from process 7 out of 8 on comet-14-02.local
Hello from thread 2 out of 6 from process 7 out of 8 on comet-14-02.local
Hello from thread 3 out of 6 from process 7 out of 8 on comet-14-02.local
Hello from thread 5 out of 6 from process 7 out of 8 on comet-14-02.local
Hello from thread 1 out of 6 from process 6 out of 8 on comet-14-02.local
```

## Using SSD Scratch

```
#!/bin/bash
#SBATCH --job-name="localscratch"
#SBATCH --output="localscratch.%j.%N.out"
#SBATCH --partition=compute
#SBATCH --nodes=1
#SBATCH --ntasks-per-node=24
#SBATCH --export=ALL
#SBATCH -t 01:30:00

#Copy binary to SSD
cp IOR.exe /scratch/$USER/$SLURM_JOBID
#Change to local scratch (SSD) and run IOR benchmark
cd /scratch/$USER/$SLURM_JOBID
#Run IO benchmark
ibrun -np 4 $WKDIR/IOR.exe -F -t 1m -b 4g -v –v >  IOR.out.$SLURM_JOBID
#Copy out data you need
cp IOR.out.$SLURM_JOBID $SLURM_SUBMIT_DIR
```

# Using SSD Scratch

- **Snapshot on the node during the run:**

```
[mahidhar@comet-20-71 ~]$ squeue -u $USER
             JOBID PARTITION     NAME     USER ST       TIME  NODES NODELIST(REASON)
          15580587   compute localscr mahidhar  R       0:11      1 comet-20-71

[mahidhar@comet-20-71 ~]$ cd /scratch/mahidhar/15580587/

[mahidhar@comet-20-71 15580587]$ ls -lt
total 9173887
-rw-r--r-- 1 mahidhar use300 1939865600 Apr 16 23:25 testFile.00000002
-rw-r--r-- 1 mahidhar use300 3865051136 Apr 16 23:25 testFile.00000000
-rw-r--r-- 1 mahidhar use300 2490368000 Apr 16 23:25 testFile.00000001
-rw-r--r-- 1 mahidhar use300 2777677824 Apr 16 23:25 testFile.00000003
-rw-r--r-- 1 mahidhar use300       1088 Apr 16 23:25 IOR.out.15580587
-rwxr-xr-x 1 mahidhar use300     346872 Apr 16 23:25 IOR.exe
```

- **Performance from single node (in log file copied back):**
  - Max Write: 606.49 MiB/sec (635.95 MB/sec)
  - Max Read: 19028.71 MiB/sec (19953.05 MB/sec)

# Multi-node SSD example

## *$HOME/UCSB2018/LOCALSCRATCH2*

```
#!/bin/bash
#SBATCH --job-name="localscratch2"
#SBATCH --output="localscratch2.%j.%N.out"
#SBATCH --partition=compute
#SBATCH --nodes=2
#SBATCH --ntasks-per-node=24
#SBATCH --export=ALL
#SBATCH -t 00:10:00

#Get a list of hosts
export SLURM_NODEFILE=`generate_pbs_nodefile`
cat $SLURM_NODEFILE > nodes.list.$SLURM_JOBID
uniq nodes.list.$SLURM_JOBID > nodes.unq.list

#Change to local scratch (SSD) and run IOR benchmark
cd /scratch/$USER/$SLURM_JOBID

#Run IO benchmark
ibrun -np 48 $SLURM_SUBMIT_DIR/IOR.exe -F -t 1m -b 4m -v -v -w

#Change back to submit dir
cd $SLURM_SUBMIT_DIR
```

```
#List files on both nodes
for (( nn=1; nn<=$SLURM_NNODES; nn++ ))
 do
   p="`sed -n ${nn}p nodes.unq.list`"
   echo "Files on $p"
   ssh $p /bin/ls /scratch/$USER/$SLURM_JOBID
 done


#Tar back the results from each node
for (( nn=1; nn<=$SLURM_NNODES; nn++ ))
 do
   p="`sed -n ${nn}p nodes.unq.list`"
   echo "Tar files on $p"
   ssh $p /bin/tar -cvf $SLURM_SUBMIT_DIR/node$nn.tar /scratch/$US
ER/$SLURM_JOBID
 done

rm nodes.unq.list
rm nodes.list.$SLURM_JOBID
```

## Intel Math Kernel Libraries (MKL)

- Installed on Comet as part of the Intel compiler distributions.
- Covers BLAS, LAPACK,FFT, BLACS, and SCALAPACK libraries.
- Most useful link for MKL: The Intel link advisor:

https://software.intel.com/en-us/articles/intel-mkl-link-line-advisor

# Intel MKL Example

- **cd /share/apps/examples/UCSB2018/MKL**
- **The compile line is available in the compile.txt file:**

```
mpicc -o pdpttr.exe pdpttr.c  -I$MKL_ROOT/include ${MKL_ROOT}/lib/intel64/libmkl
_scalapack_lp64.a -Wl,--start-group ${MKL_ROOT}/lib/intel64/libmkl_intel_lp64.a
${MKL_ROOT}/lib/intel64/libmkl_core.a ${MKL_ROOT}/lib/intel64/libmkl_sequential.
a -Wl,--end-group ${MKL_ROOT}/lib/intel64/libmkl_blacs_intelmpi_lp64.a -lpthread
 -lm
```

- **Submit script: scalapack.sb**

## Comet GPU Nodes

**2 NVIDIA K-80 Cards (4 GPUs total) per node.**

[1] CUDA code compile and run example

[2] Hands On Examples using Singularity to enable Tensorflow

## Compiling CUDA Example

- **Load the CUDA module:**

```
module load cuda
```

- **Compile the code:**

```
cd /home/$USER/UCSB2018/CUDA
nvcc -o matmul -I. matrixMul.cu
```

- **Submit the job:**

```
sbatch cuda.sb
```

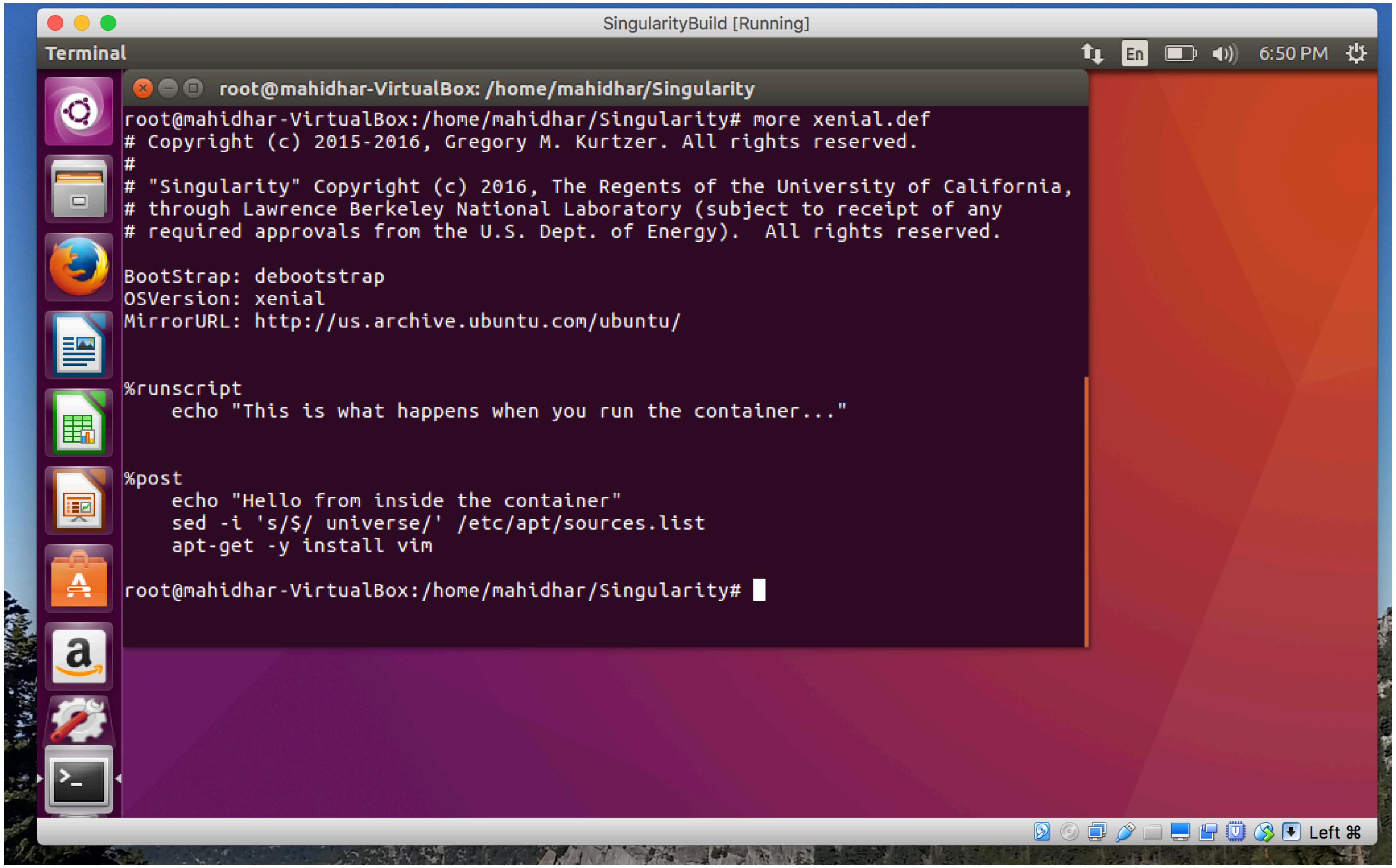
## CUDA Example: Batch Submission Script

```
#!/bin/bash
#SBATCH --job-name="CUDA"
#SBATCH --output="CUDA.%j.%N.out"
#SBATCH --partition=gpu-shared
#SBATCH --nodes=1
#SBATCH --ntasks-per-node=6
#SBATCH --gres=gpu:1
#SBATCH -t 01:00:00

#Load the cuda module
module load cuda

#Run the job
./matmul
```

## Singularity: Provides Flexibility for OS Environment

- Singularity (http://singularity.lbl.gov)is a relatively new development that has become very popular on Comet.
- Singularity allows groups to easily migrate complex software stacks from their campus to Comet.
- Singularity runs in user space, and requires very little special support – in fact it actually reduces it in some cases.
- We have roughly 15 groups running this on Comet.
- Applications include: Tensorflow, Torch, Fenics, and custom user applications.
- Docker images can be imported into Singularity.

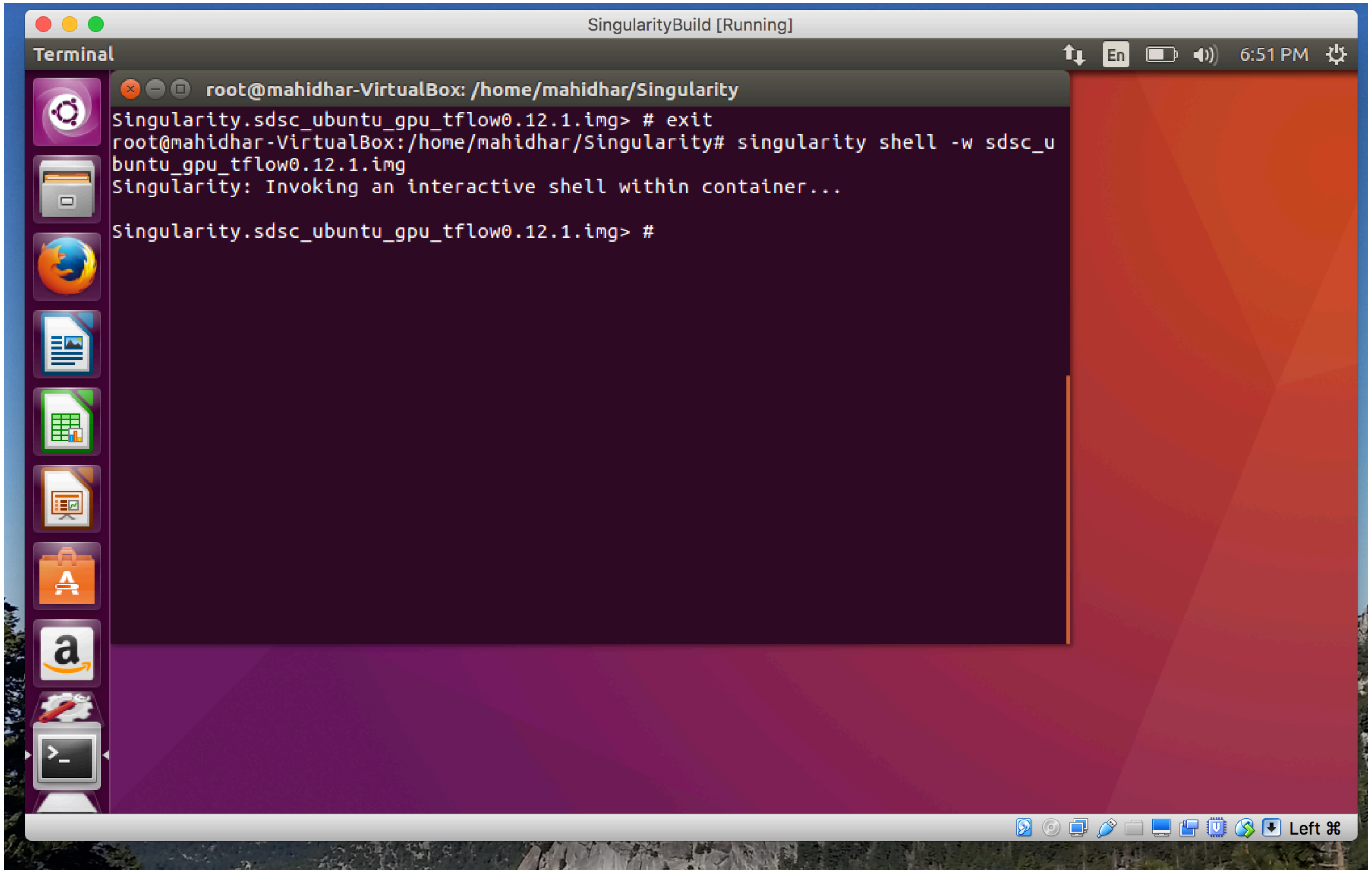
# Singularity: Provides Flexibility for OS Environment


SingularityBuild [Running]
Terminal
6:50 PM
root@mahidhar-VirtualBox: /home/mahidhar/Singularity
Left ⌘

```
root@mahidhar-VirtualBox:/home/mahidhar/Singularity# more xenial.def
# Copyright (c) 2015-2016, Gregory M. Kurtzer. All rights reserved.
#
# "Singularity" Copyright (c) 2016, The Regents of the University of California,
# through Lawrence Berkeley National Laboratory (subject to receipt of any
# required approvals from the U.S. Dept. of Energy).  All rights reserved.

BootStrap: debootstrap
OSVersion: xenial
MirrorURL: http://us.archive.ubuntu.com/ubuntu/


%runscript
    echo "This is what happens when you run the container..."


%post
    echo "Hello from inside the container"
    sed -i 's/$/ universe/' /etc/apt/sources.list
    apt-get -y install vim

root@mahidhar-VirtualBox:/home/mahidhar/Singularity#
```

- **Above snapshot shows a definition file on a virtual box on personal laptop. The definition file lets you build a singularity image.**

## Singularity: Provides Flexibility for OS Environment


SingularityBuild [Running]
Terminal
En
6:51 PM
root@mahidhar-VirtualBox: /home/mahidhar/Singularity
Left ⌘

```
Singularity.sdsc_ubuntu_gpu_tflow0.12.1.img> # exit
root@mahidhar-VirtualBox:/home/mahidhar/Singularity# singularity shell -w sdsc_u
buntu_gpu_tflow0.12.1.img
Singularity: Invoking an interactive shell within container...

Singularity.sdsc_ubuntu_gpu_tflow0.12.1.img> #
```

- **Can open image in write mode on laptop via singularity and install packages (like Tensorflow). So an existing image on Comet can serve as a starting point.**

## Singularity Image Sources

- **SDSC staff have some useful images in:**
  - /share/apps/compute/singularity
  - /share/apps/gpu/singularity
- **Users can build their own images on their laptops/desktops/cloud - as long as you have singularity installed and have root access on your own machine (or VM or cloud instance)**
- **Pull an image from Singularity Hub**
- **Import a docker image**
- **Comet specific documentation available at:**
  - http://www.sdsc.edu/support/user_guides/tutorials/about_comet_singularity_containers.html

## Tensorflow via Singularity

```
#!/bin/bash
#SBATCH --job-name="TensorFlow"
#SBATCH --output="TensorFlow.%j.%N.out"
#SBATCH --partition=gpu-shared
#SBATCH --nodes=1
#SBATCH --ntasks-per-node=6
#SBATCH --gres=gpu:1
#SBATCH -t 01:00:00

#Run the job
#

module load singularity
singularity exec /share/apps/gpu/singularity/sdsc_ubuntu_gpu_tflow.img lsb_relea
se -a
singularity exec /share/apps/gpu/singularity/sdsc_ubuntu_gpu_tflow.img python -m
 tensorflow.models.image.mnist.convolutional
```

## Tensorflow via Singularity

- **Change to the examples directory:**

```
cd /home/$USER/UCSB2018/TensorFlow
```

- **Submit the job:**

```
sbatch TensorFlow.sb
```

# Tensorflow Example: Output

```
Distributor ID: Ubuntu
Description: Ubuntu 16.04 LTS
Release: 16.04
Codename: xenial
I tensorflow/stream_executor/dso_loader.cc:108] successfully opened CUDA library libcublas.so locally
I tensorflow/stream_executor/dso_loader.cc:108] successfully opened CUDA library libcudnn.so locally
I tensorflow/stream_executor/dso_loader.cc:108] successfully opened CUDA library libcufft.so locally
I tensorflow/stream_executor/dso_loader.cc:108] successfully opened CUDA library libcuda.so.1 locally
I tensorflow/stream_executor/dso_loader.cc:108] successfully opened CUDA library libcurand.so locally
I tensorflow/core/common_runtime/gpu/gpu_init.cc:102] Found device 0 with properties:
name: Tesla K80
major: 3 minor: 7 memoryClockRate (GHz) 0.8235
pciBusID 0000:85:00.0
Total memory: 11.17GiB
Free memory: 11.11GiB
I tensorflow/core/common_runtime/gpu/gpu_init.cc:126] DMA: 0
I tensorflow/core/common_runtime/gpu/gpu_init.cc:136] 0:   Y
I tensorflow/core/common_runtime/gpu/gpu_device.cc:838] Creating TensorFlow device (/gpu:0) -> (device: 0, name:
Tesla K80, pci bus id: 0000:85:00.0)
Extracting data/train-images-idx3-ubyte.gz
…
Step 8500 (epoch 9.89), 11.6 ms
Minibatch loss: 1.601, learning rate: 0.006302
Minibatch error: 0.0%
Validation error: 0.9%
Test error: 0.9%
```

## Summary

- Comet can be directly accessed using a ssh client.
- Always run via the batch scheduler – for both interactive and batch jobs. ***Do not run on the login nodes.***
- Choose your filesystem wisely – Lustre parallel filesystem for large block I/O. SSD based filesystems for small block I/O, lots of small files. ***Do not use home filesystem for intensive I/O of any kind.***
- Comet can handle MPI, OpenMP, Pthreads, Hybrid, CUDA, and OpenACC jobs. See /share/apps/examples for details!