Introduction to Comet
Launching and Managing Jobs

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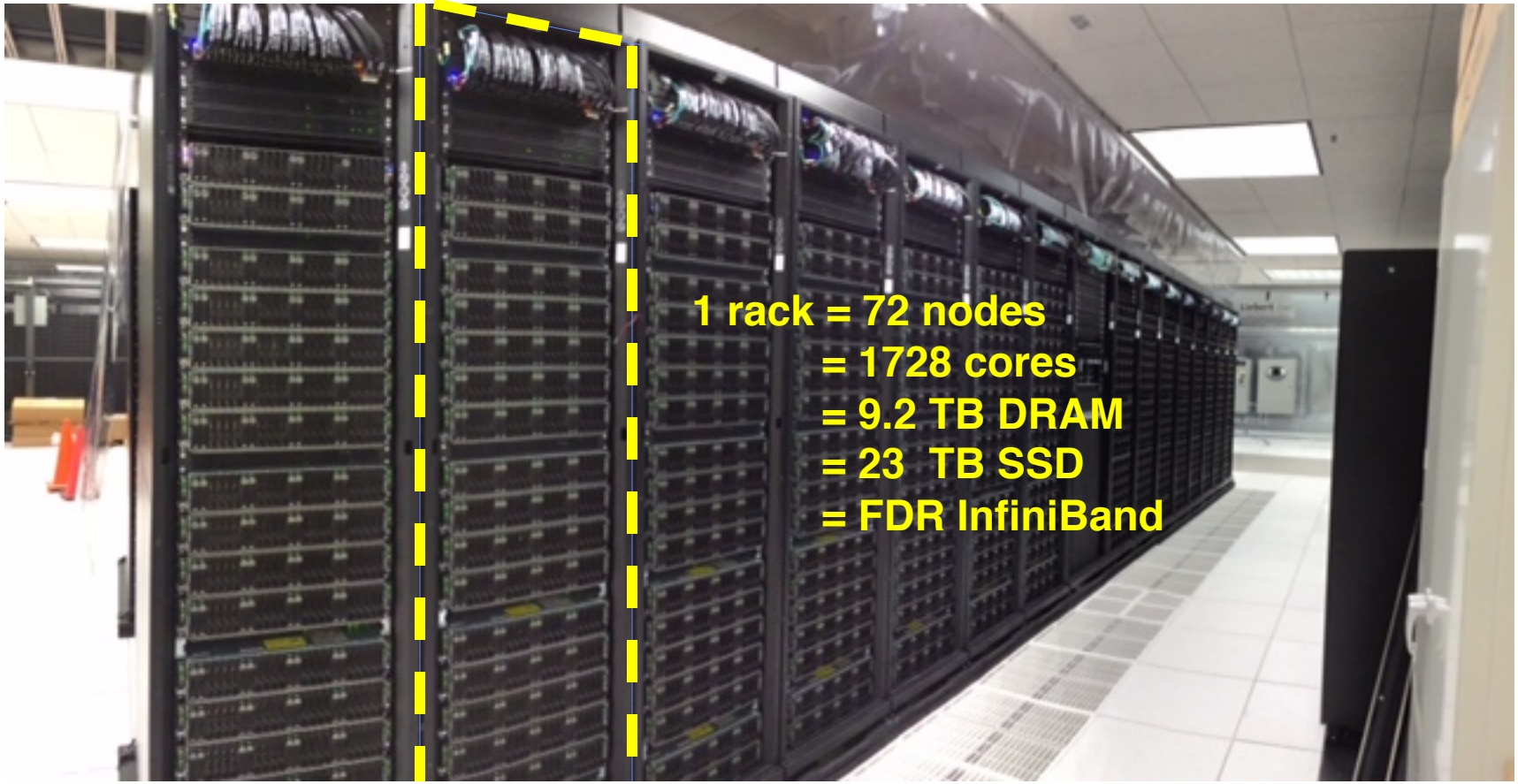
Comet
“HPC for the long tail of science”

iPhone panorama photograph of 1 of 2 server rows

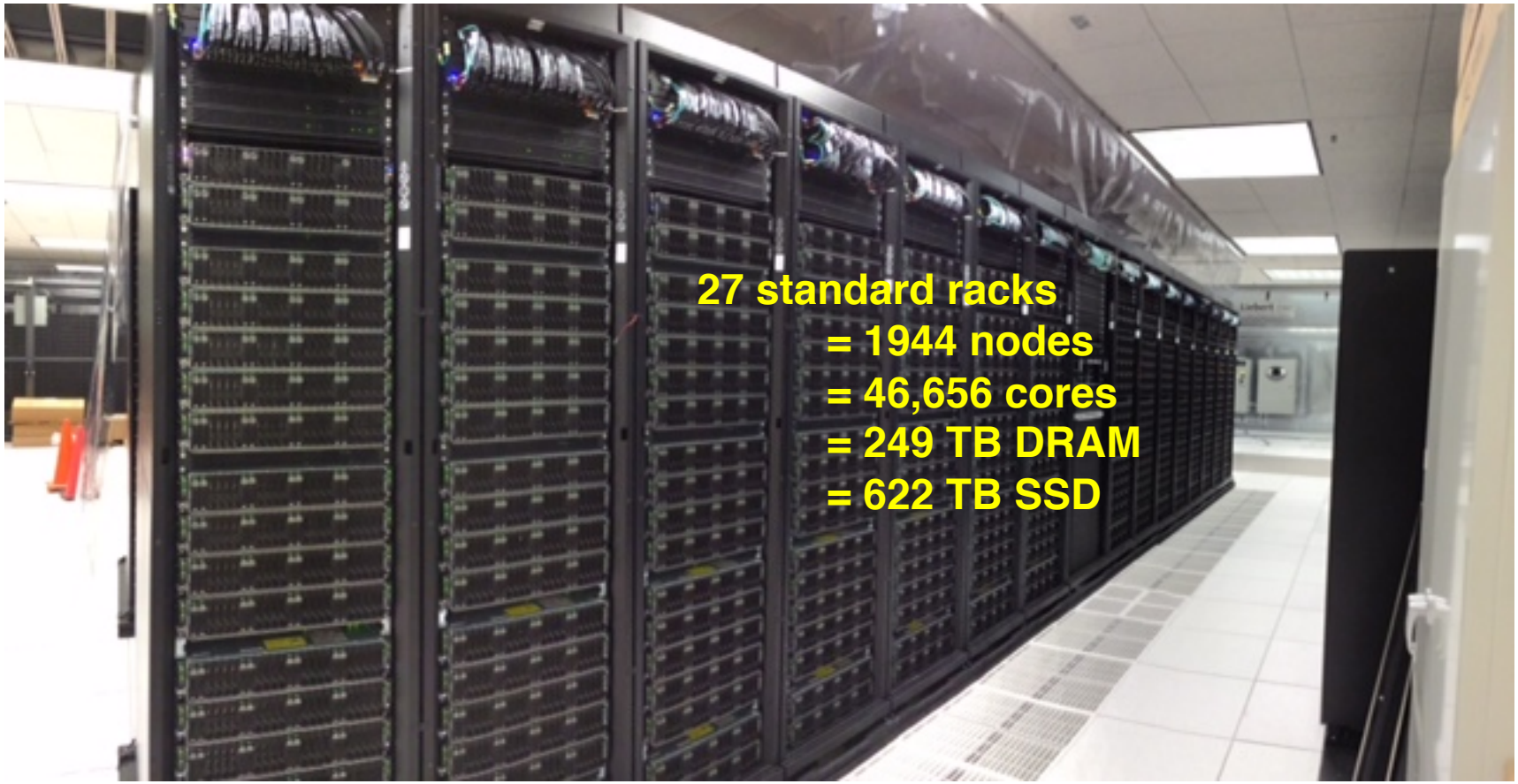
Comet: System Characteristics

- **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 2 14-core Intel Broadwell CPUs plus 4 NVIDIA P100 GPUs
- **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

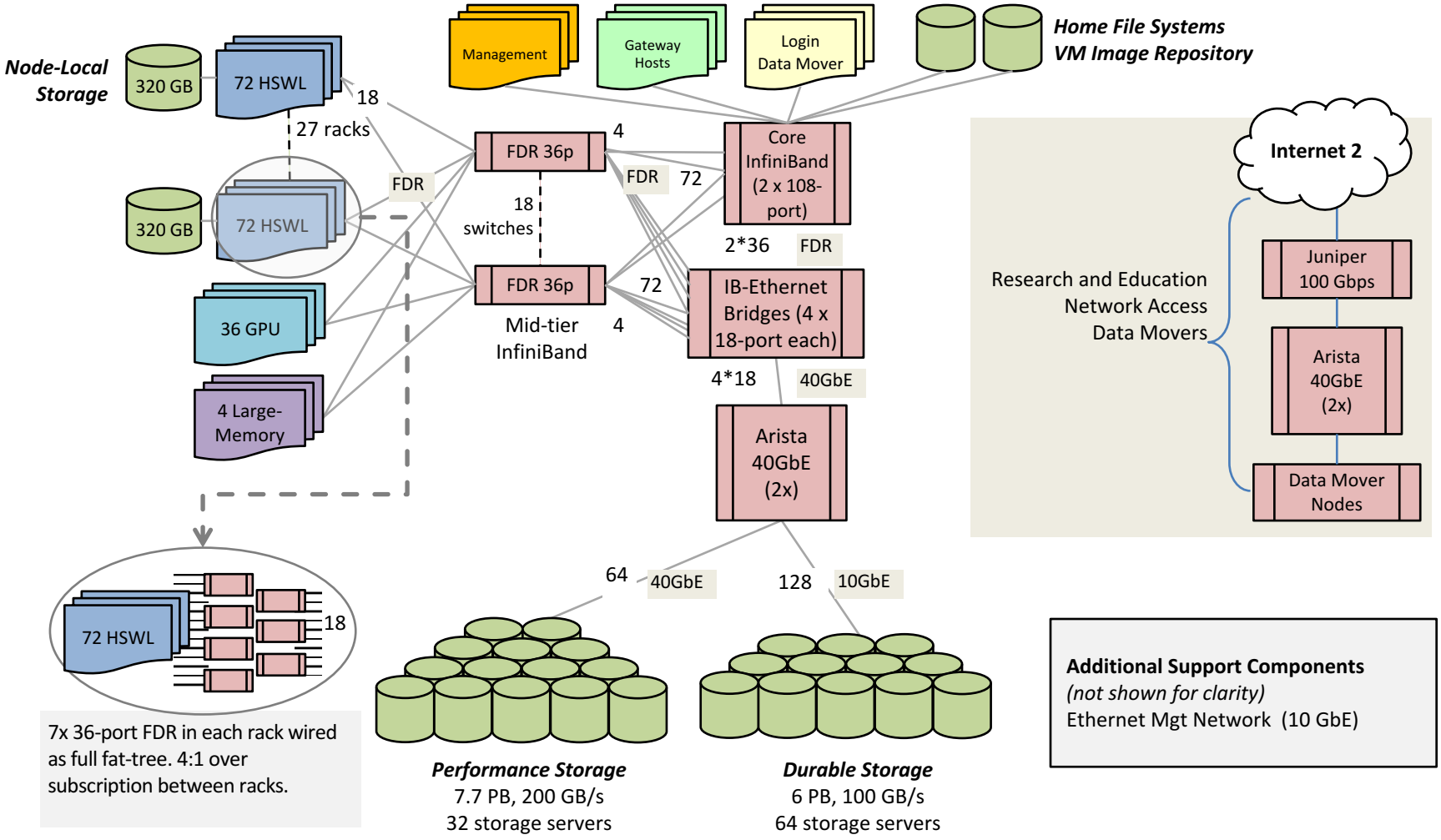


And 27 single-rack supercomputers



Comet Network Architecture

InfiniBand compute, Ethernet Storage



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

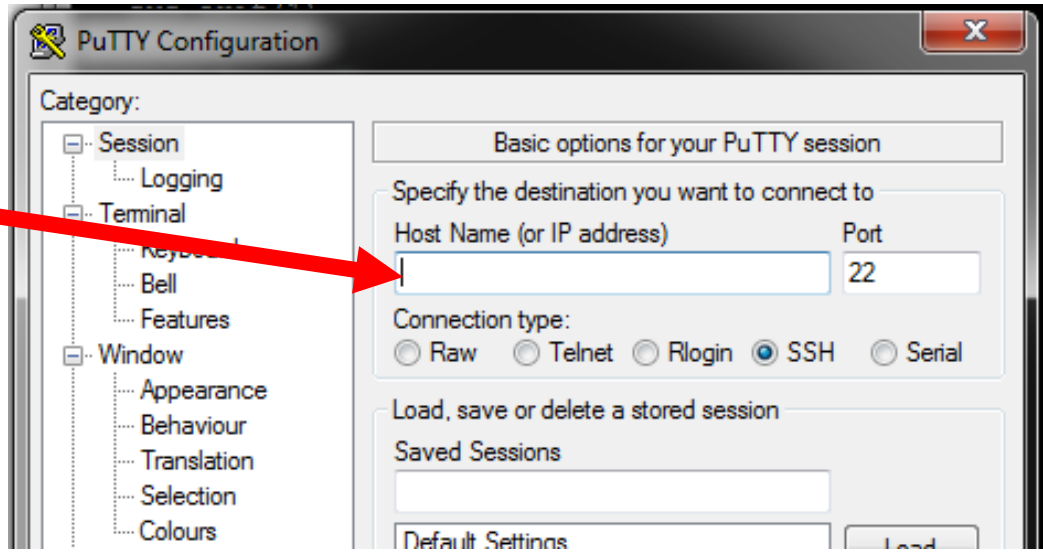
Logging into Comet

Mac/Linux:

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

Windows (PuTTY):

comet.sdsc.edu



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.*

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

Comet – Compiling/Running Jobs

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

  cd /home/$USER/SI2017/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/SI2017/MPI/IBRUN

  sbatch --res=SI2017DAY1 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 /share/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/SI2017/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 ./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:**

```
$ pwd
/scratch/mahidhar/435463
$ ls -lt
total 22548292
-rw-r--r-- 1 mahidhar hpss 5429526528 May 15 23:48 testFile.00000001
-rw-r--r-- 1 mahidhar hpss 6330253312 May 15 23:48 testFile.00000003
-rw-r--r-- 1 mahidhar hpss 5532286976 May 15 23:48 testFile.00000000
-rw-r--r-- 1 mahidhar hpss 5794430976 May 15 23:48 testFile.00000002
-rw-r--r-- 1 mahidhar hpss       1101 May 15 23:48 IOR_native_scratch.log
```

- **Performance from single node (in log file copied back):**
  - Max Write: 250.52 MiB/sec (262.69 MB/sec)
  - Max Read: 181.92 MiB/sec (190.76 MB/sec)

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/SI2017/CUDA

  nvcc -o matmul -I. matrixMul.cu

- **Submit the job:**

  sbatch --res=SI2017DAY1 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, Paraview, Torch, Fenics, and custom user applications.
- Docker images can be imported into Singularity.

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:k80:1
#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

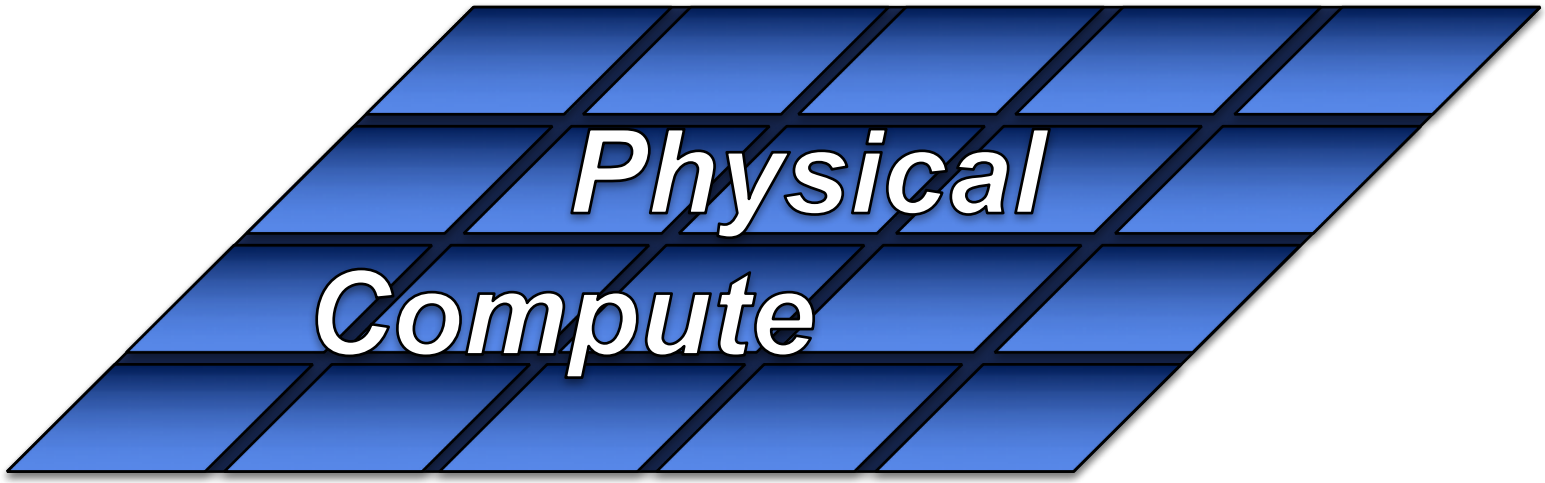
- **Change to the examples directory:**
  cd /home/$USER/SI2017/TensorFlow

- **Submit the job:**
  sbatch --res=SI2017DAY1 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%
```

Add Data Analysis to Existing Compute Infrastructure



Add Data Analysis to Existing Compute Infrastructure

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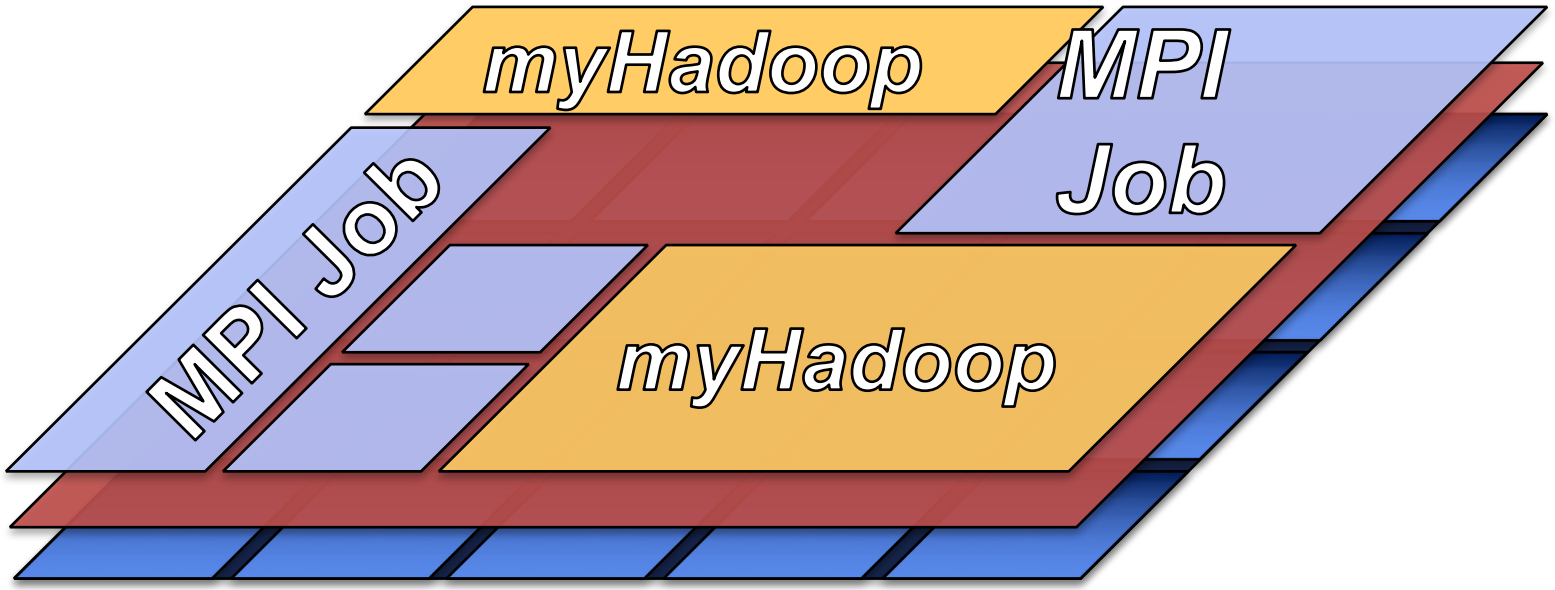
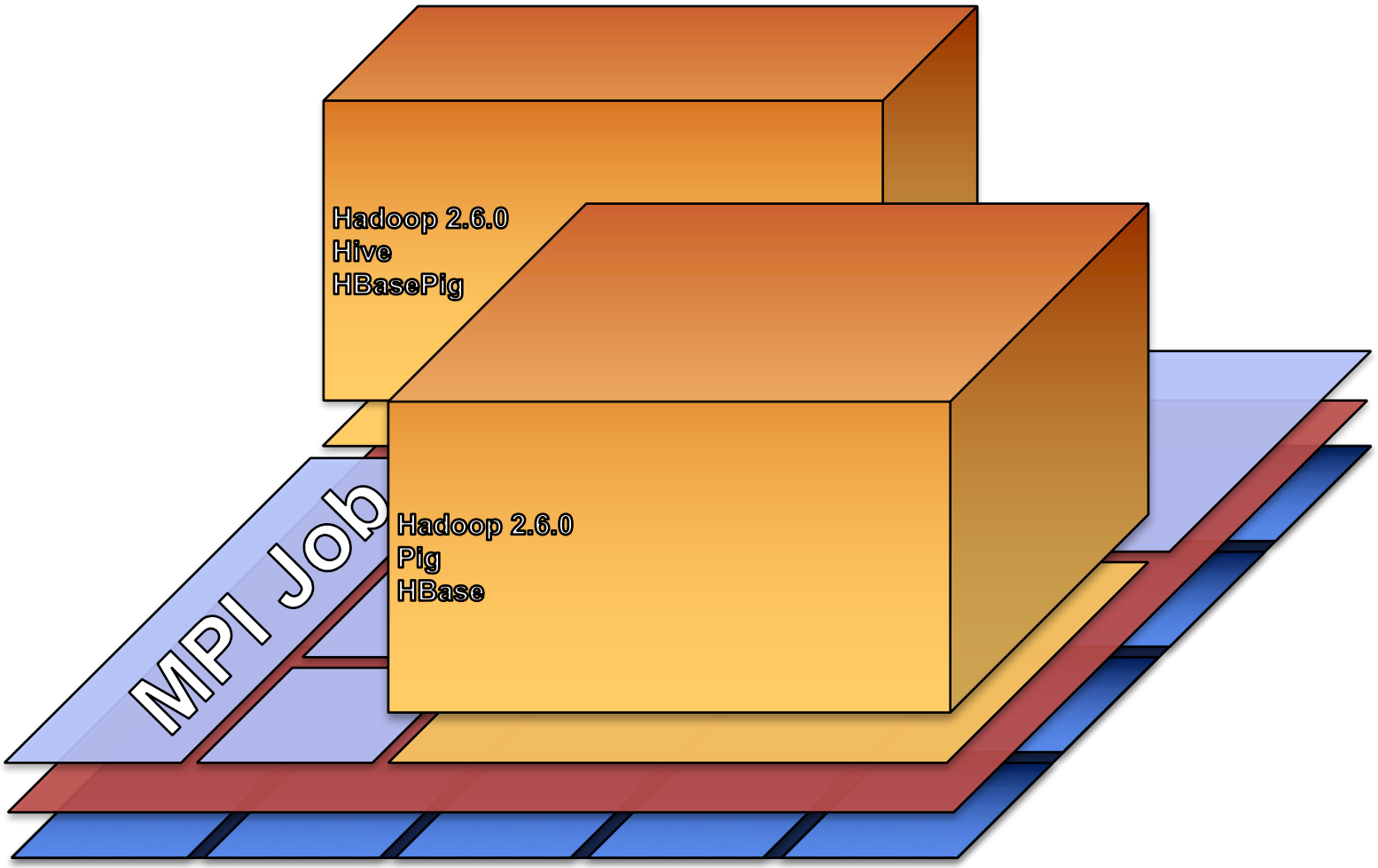


Add Data Analysis to Existing Compute Infrastructure



myHadoop – 3-step Cluster

1. Set a few environment variables

```
# sets HADOOP_HOME, JAVA_HOME, and PATH
$ module load hadoop
$ export HADOOP_CONF_DIR=$HOME/mycluster.conf
```

2. Run myhadoop-configure.sh to set up Hadoop

```
$ myhadoop-configure.sh
```

3. Start cluster with Hadoop's `start-all.sh`

```
$ start-all.sh
```

Anagram Example – Comet Submit Script

```
#!/bin/bash
#SBATCH --job-name=”Anagram"
#SBATCH --output=”Anagram.%j.%N.out"
#SBATCH –partition=compute
#SBATCH –nodes=2
#SBATCH --ntasks-per-node=24
#SBATCH --export=ALL
#SBATCH -t 01:00:00
export WRKDIR=`pwd`
myhadoop-configure.sh
start-all.sh
hadoop dfs -mkdir input
hadoop dfs -copyFromLocal $WRKDIR/SINGLE.TXT input/
hadoop jar $WRKDIR/AnagramJob.jar input/SINGLE.TXT output
hadoop dfs -copyToLocal output/part* $PBS_O_WORKDIR
stop-all.sh
myhadoop-cleanup.sh
```

ANAGRAM Example

- **Change to directory:**

  cd $HOME/SI2017/hadoop/ANAGRAM_Hadoop2

- **Submit job:**

  sbatch --res=SI2017DAY1 anagram.script

- **Check configuration in directory:**

  ls $HOME/cometcluster

Anagram Example – Sample Output

```
cat part-00000
…
aabcdelmnu        manducable,ambulanced,
aabcdeorrsst      broadcasters,rebroadcasts,
aabcdeorrst       rebroadcast,broadcaster,
aabcdkrsw         drawbacks,backwards,
aabcdkrw          drawback,backward,
aabceeehlnsst     teachableness,cheatableness,
aabceeelnnrsstu   uncreatableness,untraceableness,
aabceeelrrt       recreatable,retraceable,
aabceehlt         cheatable,teachable,
aabceellr         lacerable,clearable,
aabceelnrtu       uncreatable,untraceable,
aabceelorrrstv    vertebrosacral,sacrovertebral,
…
…
```

RDMA-Hadoop and RDMA-Spark

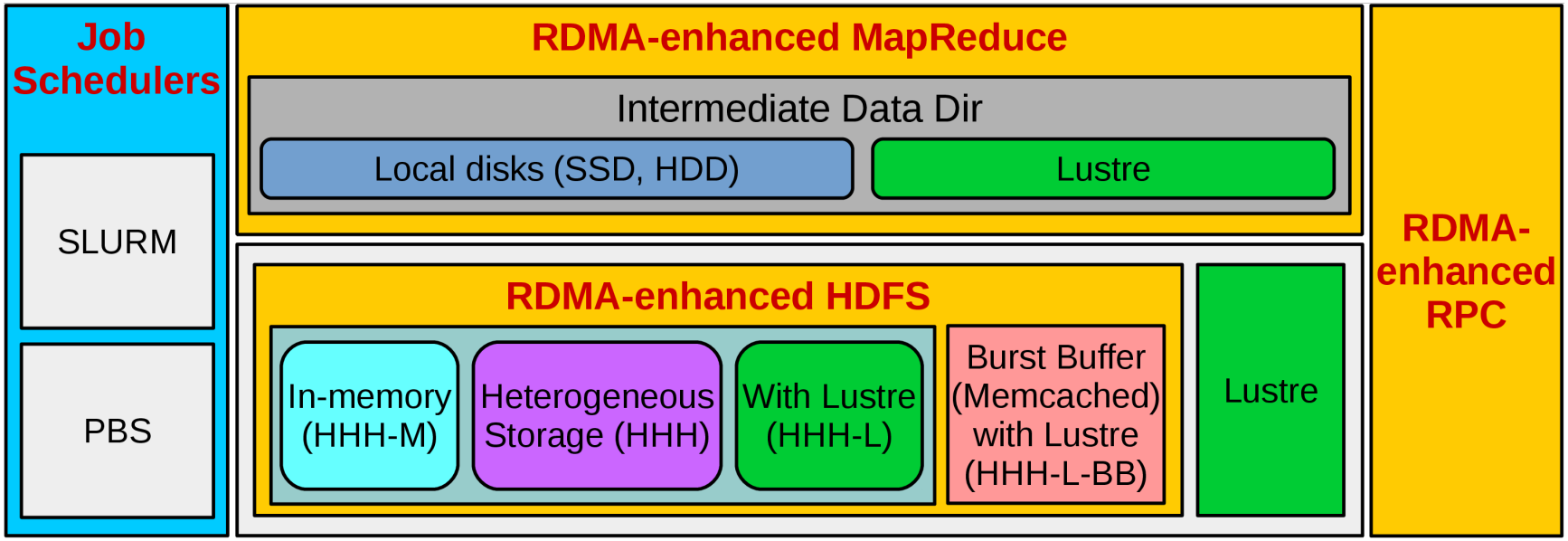
Network-Based Computing Lab, Ohio State University

NSF funded project in collaboration with Dr. DK Panda

- HDFS, MapReduce, and RPC over native InfiniBand and RDMA over Converged Ethernet (RoCE).
- Based on Apache distributions of Hadoop and Spark.
- Version RDMA-Apache-Hadoop-2.x 1.1.0 (based on Apache Hadoop 2.6.0) available on Comet
- Version RDMA-Spark 0.9.3 (based on Apache Spark 1.5.1) is available on Comet.
- More details on the RDMA-Hadoop and RDMA-Spark projects at:
  - http://hibd.cse.ohio-state.edu/

RDMA-Hadoop, Spark

- Exploit performance on modern clusters with RDMA-enabled interconnects for Big Data applications.
- Hybrid design with in-memory and heterogeneous storage (HDD, SSDs, Lustre).
- Keep compliance with standard distributions from Apache.



Hands On: Anagram using HHH-M mode

```
#!/bin/bash
#SBATCH --job-name="rdmahadoopanagram"
#SBATCH --output="rdmahadoopanagram.%j.%N.out"
#SBATCH --partition=compute
#SBATCH --nodes=3
#SBATCH --ntasks-per-node=24
#SBATCH -t 00:15:00

#Script request 3 nodes - one used for namenode, 2 for data nodes/processing

#Set modulepath and load RDMA Hadoop Module
export
MODULEPATH=/share/apps/compute/modulefiles/applications:$MODULEPATH
module load rdma-hadoop/2x-1.1.0
```

Hands On: Anagram using HHH-M mode

```
#Get the host list
export SLURM_NODEFILE=`generate_pbs_nodefile`
cat $SLURM_NODEFILE | sort -u > hosts.hadoop.list

#Use SLURM integrated configuration/startup script
hibd_install_configure_start.sh -s -n ./hosts.hadoop.list -i $SLURM_JOBID -h $HA
DOOP_HOME -j $JAVA_HOME -m hhh-m -r /dev/shm -d /scratch/$USER/$SLURM_JOBID -t /
scratch/$USER/$SLURM_JOBID/hadoop_local

#Commands to run ANAGRAM example
$HADOOP_HOME/bin/hdfs --config $HOME/conf_$SLURM_JOBID dfs -mkdir -p /user/$USER
/input
$HADOOP_HOME/bin/hdfs --config $HOME/conf_$SLURM_JOBID dfs -put SINGLE.TXT /user
/$USER/input/SINGLE.TXT
$HADOOP_HOME/bin/hadoop --config $HOME/conf_$SLURM_JOBID jar AnagramJob.jar /use
r/$USER/input/SINGLE.TXT /user/$USER/output
$HADOOP_HOME/bin/hdfs --config $HOME/conf_$SLURM_JOBID dfs -get /user/$USER/outp
ut/part* $SLURM_WORKING_DIR

#Clean up
hibd_stop_cleanup.sh -d -h $HADOOP_HOME -m hhh-m -r /dev/shm
```

RDMA-Hadoop: HHH-M Example

- **Change to directory:**

  cd $HOME/SI2017/hadoop/RDMA-Hadoop/RDMA-HHH-M

- **Submit job:**

  sbatch --res=SI2017DAY1 anagram.script

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. Singularity provides further flexibility.
- Dynamic spin up of Hadoop, Spark instances within Comet scheduler framework.