

Joint High Performance Computing Exchange (JHPCE) Cluster Orientation



JOHNS HOPKINS
BLOOMBERG SCHOOL
of PUBLIC HEALTH

<http://www.jhpce.jhu.edu/>

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Schedule

- **Introductions – who are we, who are you?**
- Terminology
- Logging in and account setup
- Basics of running programs on the cluster
- Details – limits and resources
- Examples



Who we are:

- JHPCE – Joint High Performance Computing Exchange

- Co-Director:

Brian Caffo



- Co-Director:

Mark Miller



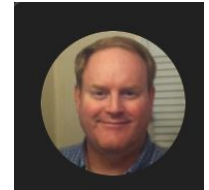
- Systems Engineer:

Jiong Yang



- Systems Engineer:

Jeffrey Tunison



- Application Developer:

Adi Gherman



Who we are – Getting help:

- Beyond this class, when you have questions:
 - <http://jhpce.jhu.edu> – JHPCE Web Site
 - Lots of good FAQ info
 - Searchable
 - You can download a copy of these slides
 - <https://jhpce-app02.jhsph.edu> – JHPCE App Portal
 - User self service (password resets)
 - Portal to Web-based Apps (Rstudio, Jupyter Labs, Visual Studio)
 - bitsupport@lists.johnshopkins.edu – System Support Email
 - System issues (password resets/disk space)
 - Monitored by the 5 people above
 - bithelp@lists.johnshopkins.edu – App Support Email
 - Application issues (R/SAS/perl...)
 - Monitored by dozens of application subject matter experts
 - All volunteers
 - Others in your lab
 - Web Search

Who are you?

- Name
- Department
- How do you plan on using the cluster? What data or applications will you be using?
- Will you be accessing the cluster from a Mac or a Windows system?
- What is your experience with Unix?
- Any experience using other clusters?



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Clusters – what and why?

What is a cluster?

- A collection of many powerful computers (**nodes**) that can be shared with many users.
- Also referred to as High Performance Computing (HPC)

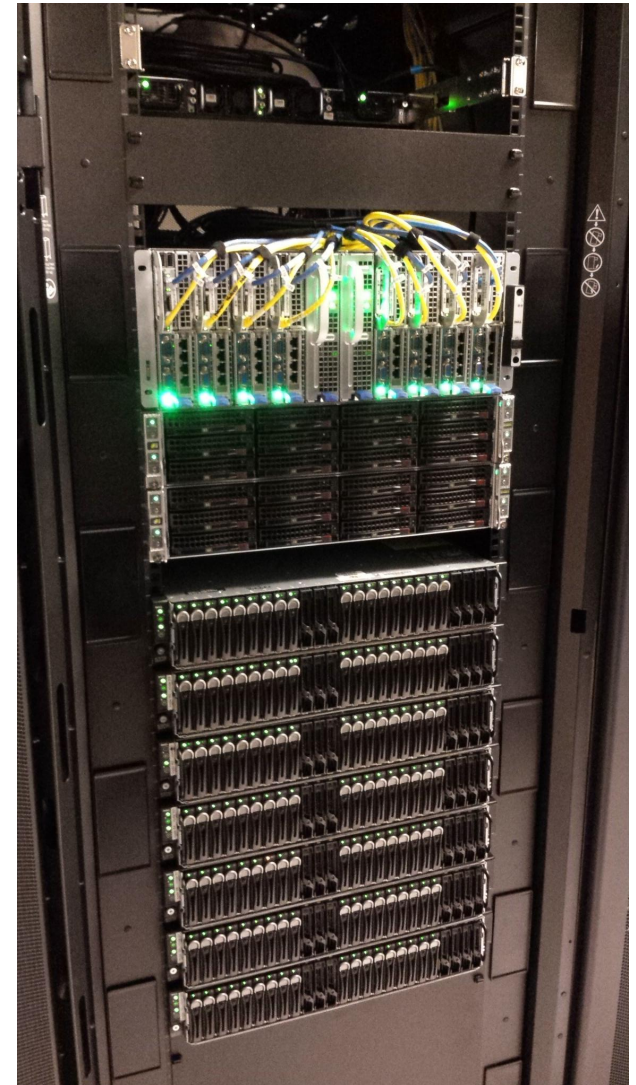
Why would you use a cluster?

- Need resources not available on your local laptop
- Need to run a program (**job**) that will run for a long time
- Need to run a job that can make use of multiple computers simultaneously (**parallel computing**)



Node (Computer) Components

- Each computer is called a “**node**”
- Each node, just like a desktop/laptop has:
 - RAM
 - Intel/AMD CPUs
 - Disk space
- Unlike desktop/laptop systems, nodes do not make use of a connected display/keyboard/mouse – they are used over a network, often from a **command line interface (CLI)** known as a “**shell**”.
- **Graphical user interface (GUI)** programs can be run, displaying on your desktop/laptop.



The JHPCE cluster components

- Joint High Performance Computing Exchange (JHPCE)
- Located at Bayview Colocation Facility ([ARCH](#))

Hardware:

- 12 Racks of equipment – 5 compute, 6 storage, 1 infra.
- 86 Nodes – 83 compute, 1 transfer, 2 login
 - 4000 Cores - Nodes have 2 - 4 CPUs, 24 to 128 cores per node
 - 46 TB of RAM - Nodes ranges from 128 GB to 2048 GB RAM.
 - Range in size from a large pizza box to a long thin shoe box
- 10 GPU nodes: 37 Nvidia V100, A100, H100, L40S GPUs
- 21,000 TB of Disk space – 18,000 TB of project storage, 2000 TB of backup, 500TB of scratch/home/other storage.
 - Storage is network-attached, available to all cluster nodes.

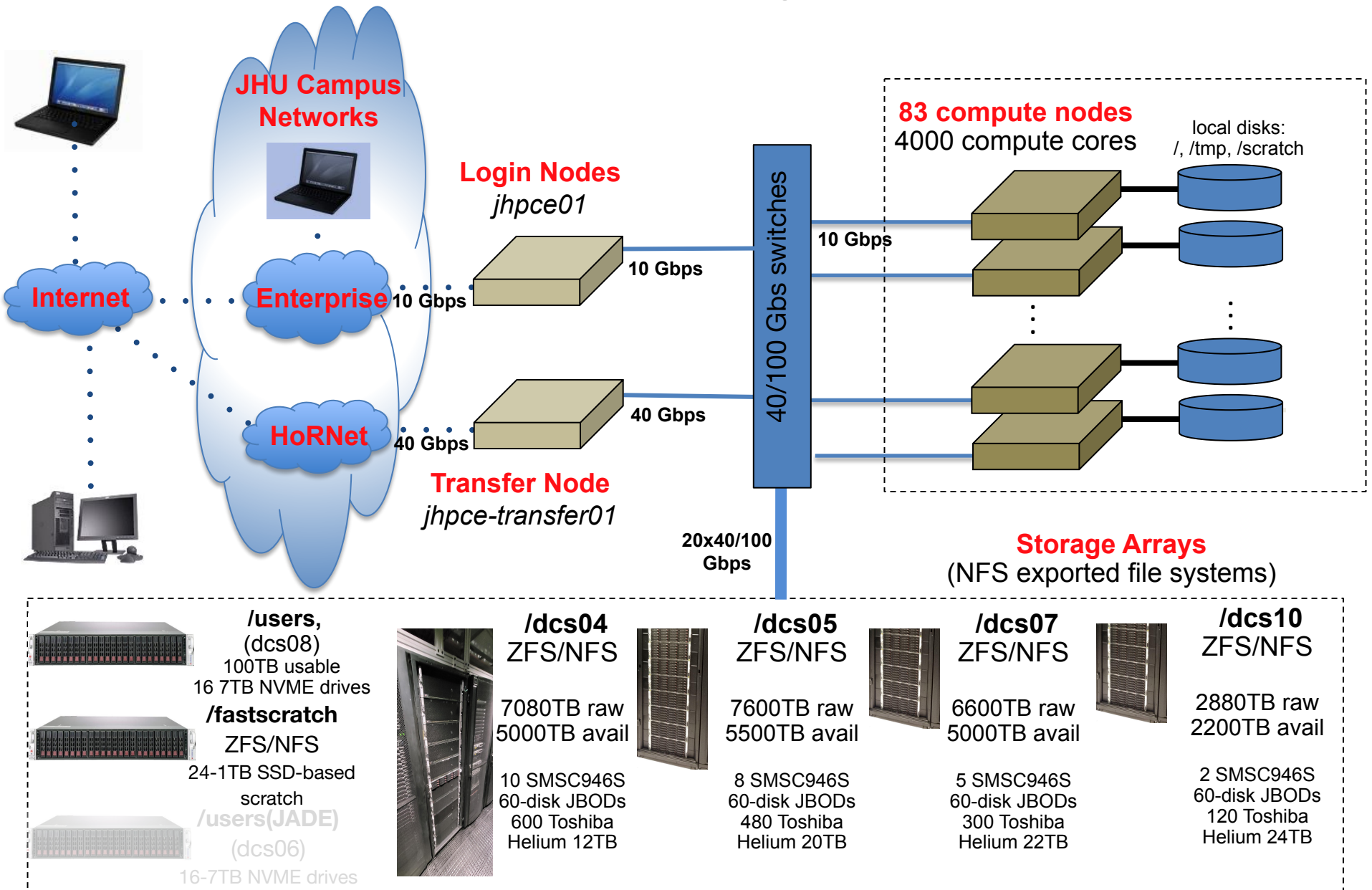
Software:

- Based on Rocky Linux 9
- Used for a wide range of Biostatistics – gene sequence analysis, population simulations, medical treatment.
- Common applications: R, SAS, Stata, python, Jupyter ...



Workstations, Desktops, Laptops

JHPCE System Architecture



SLURM Terminology

- **SLURM:** (Simple Linux Utility for Resource Management)
The scheduler for the cluster. Assigns jobs to nodes.
- **Job:** A program running under SLURM's control
- **Partition:** The queue that is used to schedule jobs to run on the nodes.
 - **shared** – The default partition
- **CPUs:** Refers to number of cores used by a job, not physical CPUs

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How do you use the cluster?

- The JHPCE cluster is accessed using SSH (Secure SHell), so you will need an ssh client.
- Use `ssh` to login to “`jhpce01.jhsph.edu`”



- For Mac and Linux users, you can use `ssh` from a Terminal application window.

- For MS Windows users, you need to install an ssh client – such as MobaXterm (strongly recommended) or Cygwin, Putty and Winscp :

<http://mobaxterm.mobatek.net/>

<http://www.chiark.greenend.org.uk/~sgtatham/putty/download.html>

<http://www.cygwin.com>

<http://winscp.net>



Quick note about graphical programs

To run graphical programs on the JHPCE cluster, you will need to have an X11 server running on your laptop.



- For Microsoft Windows, MobaXterm has an X11 server built into it.
- For Windows, if you are using Putty, you will need to install an X server such as Cygwin.



- For Macs:
 - 1) You need to have the Xquartz program installed on your laptop. This software is a free download from Apple, and does require you to reboot your laptop <http://xquartz.macosforge.org/landing/>
 - 2) You need to add the "-X" option to your ssh command:

```
$ ssh -X mmil1116@jhpce01.jhsph.edu
```

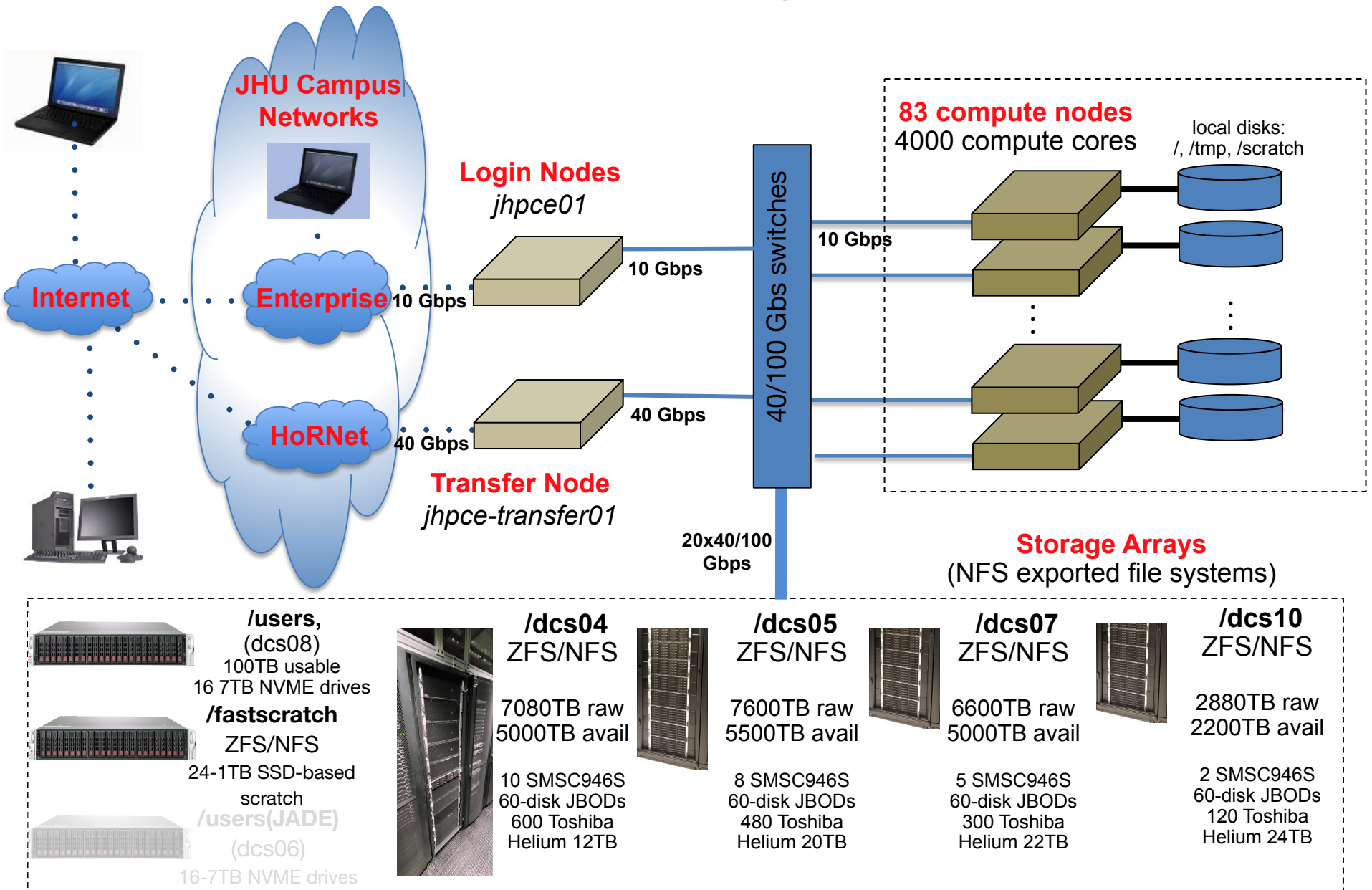


- For Linux laptops, you should already have an X11 server install. You will though need to add the -X option to ssh:

```
$ ssh -X mmil1116@jhpce01.jhsph.edu
```

Workstations, Desktops, Laptops

JHPCE System Architecture



Example 1 – Logging in



- Bring up Terminal on my Mac
- Run: `ssh -x JHPCE-USERID@jhpce01.jhsph.edu`
 - Your JHPCE-USERID is not the same as your JHED ID.
- I'm prompted for your Password and Verification Code.
 - Note that the cursor does not move when entering your Password or Verification Code
 - The Verification Code comes from my Google Authenticator app. Mine is already configured, but when you go to login for the first time, you'll use the Initial Password and Verification Code that were emailed to you. We'll set up your Authentication App in a couple of slides.
- After I login successfully, I'm sitting at a Linux Shell prompt on the jhpce01 login node.

Example 1 – Notes about logging in for the first time

- We have our own authentication system, so your JHPCE account is not the same as your JHED account. You can find your JHPCE account name (typically first initial followed by your last name) in the same email that has the Zoom link.
- We use 2-factor authentication. One factor is a Password. The second factor is via an authenticator app like Google Authenticator or Microsoft Authenticator. So, you'll need to have an Authentication app ready on your smartphone.
- As you are typing your Password and Verification Code, the cursor will not move. Don't let that throw you, the system is accepting what you're typing, it's just not being displayed back. This is a security mechanism so that someone looking over your shoulder won't be able to see your password as you're typing it.
- In my example, when I logged in I used my existing password and my Google Authenticator app. In the next slide, when you go to login for the first time, you'll use the Initial Password and Verification Code that were emailed to you earlier today. We'll go through setting your own password and configuring Google Authenticator in 2 slides.



Example 1 – Notes about logging in for the first time.. continued

- You may be prompted to change your password when you first login, so you should have a password in mind before logging in. Passwords need to be 8 characters long, and need to have 3 of these character types 1)upper case, 2)lower case, 3)number, and 4)special character
- When you ssh in, you may be prompted to accept a server key, you should say “yes” to this.
- If you enter your Password and Verification Code, and then get asked for your Password again, it means you’ve mistyped either your Password or Verification Code. You should try again, using the same Password, but using the next Verification Code in your email.
- The Verification Code is only good for 1 use, so if you type your Initial Password wrong, but your Initial Verification Codes right, it will use them up. If you repeatedly get prompted for “Password”, let me know.
- We have security software in place that will block you from logging in after 3 failed attempts, so if you try to ssh in, you’ll get a “connection timed out error. If this happens, you can let me know, and I’ll unblock you. In normal operation, this block will drop after a few minutes. For more details see: <https://jhpce.jhu.edu/access/fail2ban/>



Lab 1 - Logging In

- For Mac/Linux laptop Users:



- Bring up a Terminal
- Run: `ssh JHPCE-USERID@jhpce01.jhsph.edu`



- Login with the initial Verification Code and Password that were sent to you

- For PC Users:

- Launch MobaXterm



- click on the “Sessions” icon  in the upper left corner

- On the “Session settings” screen, click on “SSH”

- Enter “jhpce01.jhsph.edu” as the “Remote host”. Click on the “Specify username” checkbox, and enter your JHPCE-USERID in the next field. Then click the “OK” button.

- Login with the initial Verification Code and Password that were sent to you.

- If dialog windows pop up, click "Cancel" when prompted for another Verification Code, or click "No" or “Do not ask this again” when prompted to save your password.



Lab 1 - Logging In - cont

- If you did not get prompted to change your password at login, you should do that now by running the “`kpasswd`” command. You will be prompted for your current (initial) password, and then prompted for a new password.
 - Your new password must be at least 8 characters long
 - Your new password must have at least 3 of:
 - Upper case character
 - Lower case character
 - Digit
 - Special Character, such as: %\$!@
- **Setup 2 factor authentication**
 - 1) On your smartphone, bring up the "Google Authenticator" app
 - 2) On the JHPCE cluster, run "auth_util"
 - 3) In "auth_util", use option "5" to display the QR code (you may need to resize your ssh window - "view->terminal unzoom" in MobaXterm)
 - 4) Scan the QR code with the Google Authenticator app. You should see a 6 digit number with a "jhpce" title in the Google Authenticator app.

(steps continue on next slide)



Lab 1 - Logging In (cont)

- 5) Next, in "auth_util" use option 2 to display your Scratch Codes

You should record these Scratch Codes in a file for now, but print them out or store them in an encrypted file on your laptop. Don't keep them in an unencrypted file on your laptop.

Normally when logging in you will use the 6 digit number from the Google Authenticator app on your phone when prompted for "Verification Code:" during the login process. But if you don't have access to your phone, you can use one of these Scratch Codes. Each code is good for one login, so if you have these printed on a sheet of paper, you would scratch it off of the list once you use it.

The most frequent time we see these needed is when someone either breaks or trades in their phone, and they don't have Google Authenticator set up on their old phone. You would need to use one of these Scratch Codes to login to the cluster, and follow steps 1-4 above to set up the Google Authenticator app on your new phone.

- 6) In "auth_util", use option "6" to exit from "auth_util"

- Log out of the cluster by typing "exit".
- Log back into the cluster again using your own Password and the Google Authenticator code when prompted for "Verification Code"



Lab 1 - Logging In – other comments

- All users have a home directory, `/users/$USERID`, that only the user has access to by default.
- In Linux, your home directory can be referred to by `~` or **`$HOME`**
- You can use your home directory for storing programs, application, data....
- All home directories have a 100 GB limit.
- Home directories are backed up, but other storage areas are probably not.

- All users also have access to 1 TB of “fastscratch” storage for temporary data storage (less than 30 days)

<https://jhpce.jhu.edu/storage/fastscratch/>

- (optional) Setup ssh keys

<https://jhpce.jhu.edu/access/ssh/#ssh-keys>

<https://jhpce.jhu.edu/access/mobaxterm/#optional-setting-up-ssh-keys-in-mobaxterm>



General Linux/Unix Commands



Navigating Unix :

- `ls`
- `ls -l`
- `ls -al`
- `pwd`
- `cd`
- `.` and `..`
- `~` and `$HOME`

Looking at files :

- `more/less`

Commands in example script :

- `date`
- `echo`
- `hostname`
- `sleep`
- `control-C`

Changing files with editors :

- `nano`
- `vi/emacs`
- `gedit (with X11)`

Good resources for learning Linux:

http://korflab.ucdavis.edu/Unix_and_Perl/unix_and_perl_v3.1.1.html

<https://www.digitalocean.com/community/tutorials/a-linux-command-line-primer>

<https://files.fosswire.com/2007/08/fwunixref.pdf>

File Commands	System Info
ls – directory listing	date – show the current date and time
ls -al – formatted listing with hidden files	cal – show this month's calendar
cd dir – change directory to <i>dir</i>	uptime – show current uptime
cd – change to home	w – display who is online
pwd – show current directory	whoami – who you are logged in as
mkdir dir – create a directory <i>dir</i>	finger user – display information about <i>user</i>
rm file – delete <i>file</i>	uname -a – show kernel information
rm -r dir – delete directory <i>dir</i>	cat /proc/cpuinfo – cpu information
rm -f file – force remove <i>file</i>	cat /proc/meminfo – memory information
rm -rf dir – force remove directory <i>dir</i> *	man command – show the manual for <i>command</i>
cp file1 file2 – copy <i>file1</i> to <i>file2</i>	df – show disk usage
cp -r dir1 dir2 – copy <i>dir1</i> to <i>dir2</i> ; create <i>dir2</i> if it doesn't exist	du – show directory space usage
mv file1 file2 – rename or move <i>file1</i> to <i>file2</i> if <i>file2</i> is an existing directory, moves <i>file1</i> into directory <i>file2</i>	free – show memory and swap usage
ln -s file link – create symbolic link <i>link</i> to <i>file</i>	whereis app – show possible locations of <i>app</i>
touch file – create or update <i>file</i>	which app – show which <i>app</i> will be run by default
cat > file – places standard input into <i>file</i>	
more file – output the contents of <i>file</i>	Compression
head file – output the first 10 lines of <i>file</i>	tar cf file.tar files – create a tar named <i>file.tar</i> containing <i>files</i>
tail file – output the last 10 lines of <i>file</i>	tar xf file.tar – extract the files from <i>file.tar</i>
tail -f file – output the contents of <i>file</i> as it grows, starting with the last 10 lines	tar czf file.tar.gz files – create a tar with Gzip compression
Process Management	tar xzf file.tar.gz – extract a tar using Gzip
ps – display your currently active processes	tar cjf file.tar.bz2 files – create a tar with Bzip2 compression
top – display all running processes	tar xjf file.tar.bz2 – extract a tar using Bzip2
kill pid – kill process id <i>pid</i>	gzip file – compresses <i>file</i> and renames it to <i>file.gz</i>
killall proc – kill all processes named <i>proc</i> *	gzip -d file.gz – decompresses <i>file.gz</i> back to <i>file</i>
bg – lists stopped or background jobs; resume a stopped job in the background	
fg – brings the most recent job to foreground	Network
fg n – brings job <i>n</i> to the foreground	ping host – ping <i>host</i> and output results
File Permissions	whois domain – get whois information for <i>domain</i>
chmod octal file – change the permissions of <i>file</i> to <i>octal</i> , which can be found separately for user, group, and world by adding:	dig domain – get DNS information for <i>domain</i>
4 – read (r)	dig -x host – reverse lookup <i>host</i>
2 – write (w)	wget file – download <i>file</i>
1 – execute (x)	wget -c file – continue a stopped download
Examples:	Installation
chmod 777 – read, write, execute for all	Install from source:
chmod 755 – rwx for owner, rx for group and world	./configure
For more options, see man chmod .	make
	make install
	dpkg -i pkg.deb – install a package (Debian)
	rpm -Uvh pkg.rpm – install a package (RPM)
SSH	Shortcuts
ssh user@host – connect to <i>host</i> as <i>user</i>	Ctrl +C – halts the current command
ssh -p port user@host – connect to <i>host</i> on port <i>port</i> as <i>user</i>	Ctrl +Z – stops the current command, resume with fg in the foreground or bg in the background
ssh-copy-id user@host – add your key to <i>host</i> for <i>user</i> to enable a keyed or passwordless login	Ctrl +D – log out of current session, similar to exit
Searching	Ctrl +W – erases one word in the current line
grep pattern files – search for <i>pattern</i> in <i>files</i>	Ctrl +U – erases the whole line
grep -r pattern dir – search recursively for <i>pattern</i> in <i>dir</i>	Ctrl +R – type to bring up a recent command
command grep pattern – search for <i>pattern</i> in the output of <i>command</i>	!! – repeats the last command
locate file – find all instances of <i>file</i>	exit – log out of current session

* use with extreme caution.



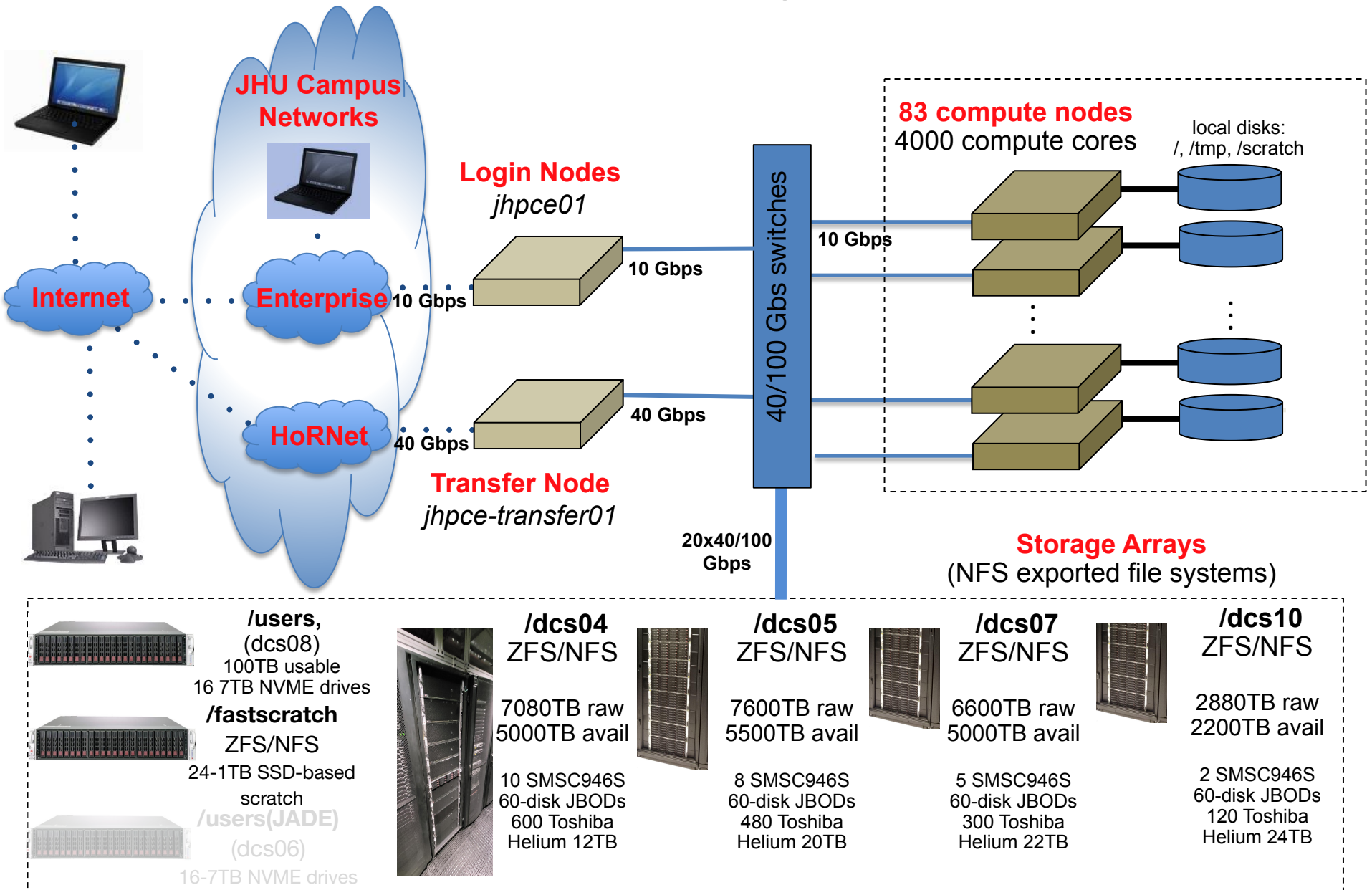
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JHPCE System Architecture



Primary SLURM Commands

2 Main SLURM commands for utilizing the cluster:

- `sbatch` – submit a batch job to the cluster
- `srun --pty --x11 bash` – establish an interactive session

Other SLURM Commands for getting info on jobs & the cluster:

- `scancel` – cancel or pause a job
- `squeue` – see the status of running & pending jobs
- `sacct` – see the status of past (& running) jobs
- `sinfo` – see status of the compute nodes
- `scontrol show job` – see statistics from running jobs

JHPCE Written Scripts for getting info on jobs & the cluster:

- `smem` – show summary of RAM usage for running jobs
- `slurmpic` – show table of compute node usage



Lab 2 - Using the SLURM cluster

Example 2a – submitting a **batch** job

```
cd class-scripts  
sbatch script1  
queue --me
```

examine results file with the `more` command
`more slurm-JOBID.out`

Example 2b – establish an **interactive** session

```
srun --pty --x11 bash  
ls  
bash script1
```

Note that output is displayed on the screen rather than saved in a file



Modules

Modules are sets of configuration information which change your environment to suit a particular software package.

We have modules for R, SAS, Mathematica, python, . . .

- module list
- module avail
- module avail stata
- module load
- module load fresh
- module unload
- module describe



Difference between Batch and Interactive

Batch Jobs:

- Running long-running jobs
- Batch Jobs continue to run even if you log off or get disconnected from the cluster
- You can submit multiple jobs

Interactive Sessions:

- Running short jobs
- Writing and debugging programs
- Running test on subset of data prior to submitting long-running batch job on full dataset
- Running graphical programs
- An interactive session ends and your jobs is terminated if your connection to the cluster is disconnected (laptop reboot, network drops)
 - any unsaved changes may be lost
 - programs will be terminated and may leave truncated results

Never run a job on the login node!

Login nodes have many fewer resources than the compute nodes. They are a shared resource.

- Always use "`sbatch`" or "`srun`" to make use of the compute nodes
- Jobs that are found running on the login node may be killed at will
- If you are going to be compiling programs, do so on a compute node via `srun`.
- Even something as simple as copying large files should be done via `srun` or `sbatch`



Other useful SLURM commands

queue – shows information about running & pending jobs

```
queue # defaults to all jobs for all users
```

```
queue --me -t r,pd # just my running & pending jobs
```

scontrol show job – shows summary info about running jobs

```
scontrol show job JOBID
```

sacct – shows information about completed jobs

```
sacct -j JOBID
```

```
sacct --helpformat (lists avail info fields)
```

```
sacct --units=M -j JOBID -o JobID,JobName,MaxVMSize,Elapsed,TotalCPU
```

scancel – deletes your job (you can also can pause them)

```
scancel JOBID
```



Primary Commands – SLURM

(Simple Linux Utility for
Resource Management)

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- `jobson`





Job Submission

salloc - Obtain a job allocation.

sbatch - Submit a batch script for later execution.

srun - Obtain a job allocation (as needed) and execute an application.

<code>--array=<indexes></code> (e.g. <code>--array=1-10</code>)	Job array specification. (sbatch command only)
<code>--account=<name></code>	Account to be charged for resources used.
<code>--begin=<time></code> (e.g. <code>--begin=18:00:00</code>)	Initiate job after specified time.
<code>--clusters=<name></code>	Cluster(s) to run the job. (sbatch command only)
<code>--constraint=<features></code>	Required node features.
<code>--cpu-per-task=<count></code>	Number of CPUs required per task.
<code>--dependency=<state:jobid></code>	Defer job until specified jobs reach specified state.
<code>--error=<filename></code>	File in which to store job error messages.
<code>--exclude=<names></code>	Specific host names to exclude from job allocation.
<code>--exclusive[=user]</code>	Allocated nodes can not be shared with other jobs/users.
<code>--export=<name[=value]></code>	Export identified environment variables.
<code>--gres=<name[:count]></code>	Generic resources required per node.
<code>--input=<name></code>	File from which to read job input data.
<code>--job-name=<name></code>	Job name.
<code>--label</code>	Prepend task ID to output. (srun command only)
<code>--licenses=<name[:count]></code>	License resources required for entire job.

<code>--mem=<MB></code>	Memory required per node.
<code>--mem-per-cpu=<MB></code>	Memory required per allocated CPU.
<code>-N<minnodes[:maxnodes]></code>	Node count required for the job.
<code>-n<count></code>	Number of tasks to be launched.
<code>--odelist=<names></code>	Specific host names to include in job allocation.
<code>--output=<name></code>	File in which to store job output.
<code>--partition=<names></code>	Partition/queue in which to run the job.
<code>--qos=<name></code>	Quality Of Service.
<code>--signal[=B:]<num>[@time]</code>	Signal job when approaching time limit.
<code>--time=<time></code>	Wall clock time limit.
<code>--wrap=<command_string></code>	Wrap specified command in a simple "sh" shell. (sbatch command only)

Accounting

sacct - Display accounting data.

<code>--allusers</code>	Displays all users jobs.
<code>--accounts=<name></code>	Displays jobs with specified accounts.
<code>--endtime=<time></code>	End of reporting period.
<code>--format=<spec></code>	Format output.
<code>--name=<jobname></code>	Display jobs that have any of these name(s).
<code>--partition=<names></code>	Comma separated list of partitions to select jobs and job steps from.
<code>--state=<state_list></code>	Display jobs with specified states.
<code>--starttime=<time></code>	Start of reporting period.

SchedMD
Slurm Support and Development

sacctmgr - View and modify account information.

Options:

<code>--immediate</code>	Commit changes immediately.
<code>--parseable</code>	Output delimited by <code>'</code>

Commands:

<code>add <ENTITY> <SPECS></code>	Add an entity. Identical to the create command.
<code>create <ENTITY> <SPECS></code>	
<code>delete <ENTITY> where <SPECS></code>	Delete the specified entities.
<code>list <ENTITY> [<SPECS>]</code>	Display information about the specific entity.
<code>modify <ENTITY> where <SPECS> set <SPECS></code>	Modify an entity.

Entities:

<code>account</code>	Account associated with job.
<code>cluster</code>	ClusterName parameter in the <code>slurm.conf</code> .
<code>qos</code>	Quality of Service.
<code>user</code>	User name in system.

Job Management

sbatch - Transfer file to a job's compute nodes.

`sbatch [options] SOURCE DESTINATION`

<code>--force</code>	Replace previously existing file.
<code>--preserve</code>	Preserve modification times, access times, and access permissions.

scancel - Signal jobs, job arrays, and/or job steps.

<code>--account=<name></code>	Operate only on jobs charging the specified account.
<code>--name=<name></code>	Operate only on jobs with specified name.
<code>--partition=<names></code>	Operate only on jobs in the specified partition/queue.
<code>--qos=<name></code>	Operate only on jobs using the specified quality of service.

--reservation=<name>	Operate only on jobs using the specified reservation.
--state=<names>	Operate only on jobs in the specified state.
--user=<name>	Operate only on jobs from the specified user.
--nodelist=<names>	Operate only on jobs using the specified compute nodes.

queue - View information about jobs.

--account=<name>	View only jobs with specified accounts.
--clusters=<name>	View jobs on specified clusters.
--format=<spec> (e.g. "--format=%i %j")	Output format to display. Specify fields, size, order, etc.
--jobs=<job_id_list>	Comma separated list of job IDs to display.
--name=<name>	View only jobs with specified names.
--partition=<names>	View only jobs in specified partitions.
--priority	Sort jobs by priority.
--qos=<name>	View only jobs with specified Qualities Of Service.
--start	Report the expected start time and resources to be allocated for pending jobs in order of increasing start time.
--state=<names>	View only jobs with specified states.
--users=<names>	View only jobs for specified users.

sinfo - View information about nodes and partitions.

--all	Display information about all partitions.
--dead	If set, only report state information for non-responding (dead) nodes.

--format=<spec>	Output format to display.
--iterate=<seconds>	Print the state at specified interval.
--long	Print more detailed information.
--Node	Print information in a node-oriented format.
--partition=<names>	View only specified partitions.
--reservation	Display information about advanced reservations.
-R	Display reasons nodes are in the down, drained, fail or failing state.
--state=<names>	View only nodes specified states.

scontrol - Used view and modify configuration and state. Also see the sview graphical user interface version.

--details	Make show command print more details.
--onliner	Print information on one line.

Commands:

create SPECIFICATION	Create a new partition or .
delete SPECIFICATION	Delete the entry with the specified SPECIFICATION
reconfigure	All Slurm daemons will re-read the configuration file.
request JOB_LIST	Request a running, suspended or completed batch job.
show ENTITY ID	Display the state of the specified entity with the specified identification
update SPECIFICATION	Update job, step, node, partition, or reservation configuration per the supplied specification.

Environment Variables

SLURM_ARRAY_JOB_ID	Set to the job ID if part of a job array.
--------------------	---

SLURM_ARRAY_TASK_ID	Set to the task ID if part of a job array.
SLURM_CLUSTER_NAME	Name of the cluster executing the job.
SLURM_CPUS_PER_TASK	Number of CPUs requested per task.
SLURM_JOB_ACCOUNT	Account name.
SLURM_JOB_ID	Job ID.
SLURM_JOB_NAME	Job Name.
SLURM_JOB_NODELIST	Names of nodes allocated to job.
SLURM_JOB_NUM_NODES	Number of nodes allocated to job.
SLURM_JOB_PARTITION	Partition/queue running the job.
SLURM_JOB_UID	User ID of the job's owner.
SLURM_JOB_USER	User name of the job's owner.
SLURM_RESTART_COUNT	Number of times job has restarted.
SLURM_PROCID	Task ID (MPI rank).
SLURM_STEP_ID	Job step ID.
SLURM_STEP_NUM_TASKS	Task count (number of MPI ranks).

Daemons

slurmctld	Executes on cluster's "head" node to manage workload.
slurmd	Executes on each compute node to locally manage resources.
slurmdbd	Manages database of resources limits, licenses, and archives accounting records.

SchedMD **slurm**
Slurm Support and Development workload manager

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<http://www.schedmd.com>

Schedule

- Introductions – who are we, who are you?
- Terminology
- Logging in and account setup
- Basics of running programs on the cluster
- **Details – limits and resources**
- Examples



Requesting additional Cores

- By default, when you submit a job with sbatch, or run srun, you are allotted 5GB of RAM and 1 core for your job.
- You can request more cores with the --cpus-per-task option to sbatch and srun.

- Examples:

```
sbatch --cpus-per-task=4 job1.sh
```

or

```
srun --cpus-per-task=6 --pty --x11 bash
```



Types of parallelism on JHPCE

1. Embarrassingly (obviously) parallel ...

http://en.wikipedia.org/wiki/Embarrassingly_parallel

2. Multi-core (or multi-threaded) – a single job using multiple CPU cores via program threads on a single machine (cluster node). Also see discussion of fine-grained vs coarse-grained parallelism at

http://en.wikipedia.org/wiki/Parallel_computing



Requesting additional RAM

- By default, when you submit a job with sbatch, or run srun, you are allotted 5GB of RAM and 1 core for your job.
- You can request more or less RAM via 2 options:
 - `--mem` : memory per node (for all cores used)
 - `--mem-per-cpu` : memory per core (harder to accurately estimate)
- Examples:
 - `sbatch --mem=10G job1.sh`
 - This would give your batch job a total of 10GB of RAM
 - `srun --mem-per-cpu=5G --cpus-per-task=4 --pty --x11 bash`
 - This would give your interactive session a total of 20GB of RAM and 4 cores

Estimating RAM usage

- There is no easy formula to know ahead of time how much RAM a job will need when working with large data.
- You can run a test job on a small subset of data.
- A good place to start is the size of the files you will be reading in. Add a bit extra, as a starting point.
- You can run `sacct` to gather info on a completed job:

```
sacct -o JobID,JobName,ReqTRES%40,MaxVMSize,MAXRSS,State%20 -j JOBID
```
- Try to make your RAM request slightly higher than your expected usage.
 - Too low and your job will get killed for exceeding your request
 - Too high and your job may take longer to get scheduled, plus you'll be squatting on RAM that others can use.
- Use `slurmpic` to see the current core and RAM availability, and plan accordingly.

Setting a time limit for your job

- By default, when you submit a job with sbatch, or run srun, you will have a 1 day time limit for your job.
- You can request more time with the --time option to sbatch and srun with the time in the format of DAYS-HH:MM:SS.

Examples:

- To set a 4 day limit for your job:

```
sbatch --time=4-00:00:00 job1.sh
```

- To set an 8 hour time limit for your interactive session:

```
srun --time=08:00:00 --pty --x11 bash
```

- Shorter jobs are given higher priority via the “backfill scheduler”
- More information at: <https://jhpce.jhu.edu/slurm/time-limits/>



Email notification on sbatch job completion

- Rather than checking on your long-running job from time to time, you can add options to sbatch to receive an email when your job completes or fails by adding the mail-type and mail-user options:

```
$ sbatch --mail-type=FAIL,END --mail-user=john@jhu.edu script2
```

- Note that email notification is a great option for a **handful** of long running jobs. This is a **horrible** option for 1000s of jobs, and has caused users to have their email accounts suspended as it has appeared that they were getting spammed.



Supplying options to your sbatch job

- You can supply SLURM directives to sbatch in 4 ways:
- Order of precedence:

1. On the command line

```
$ sbatch --mem=10G --cpus-per-task=6 --mail-type=FAIL,END --mail-user=john@jhu.edu script2
```

2. Environment variable

3. Embedding them in your batch job script

Lines which start with “#SBATCH” are interpreted as options to `sbatch`. Such lines must:

- start at the very beginning of a line
- come after the interpreter line `#!/bin/bash`
- come before any commands
- There is an example in the class-scripts directory:

```
[login-31 /users/mmill116/class-scripts]$ more script1-resource-request
#!/bin/bash
#
#SBATCH --mem=10G
#SBATCH --cpus-per-task=6
#SBATCH --mail-type=FAIL,END
#SBATCH --mail-user=marcus@jhu.edu
```

```
date
```

```
. . .
```



Supplying options to your sbatch job (cont'd)

4. In your `~/.slurm/defaults` file

Syntax is: [`<command>:`][`<cluster>:`] `<option>` = `<value>`

Where [] indicates an optional argument

Command can be one of (at least): `srun`, `sbatch`, `salloc`
(But perhaps other commands also refer to the file.)

You need to specify an asterisk in between colons

We have not tested blank or commented lines.

Example contents:

```
mem=2GB
mail-user=franksmith@jh.edu
srun:*:partition=debug
sbatch:*:mail-type=FAIL,END
```



“How many jobs can I run?”

There is a limit of 10,000 pending or running jobs than any user can have. If you anticipate the need to submit more than 1,000 jobs, please email us at bitsupport@lists.jhu.edu as there are mechanisms and strategies for efficiently handling 1000s of jobs using array jobs.

More importantly, we impose a per-user limit on the number of cores and RAM for **running** jobs on the shared queue. Currently, the limit is set to **400 cores per user and 2.5TB of RAM per user**.

So, if a user submits 1,000 single-core jobs, the first 400 will begin immediately (assuming the cluster has 400 cores available on the shared queue), and the rest will remain in the ‘PD’ state until the first 400 jobs start to finish. As jobs complete, the cluster will start running ‘PD’ jobs, and keep the number of running jobs at 400.

Similarly, if a user's job requests 100GB of RAM to run, the user would only be able to run 25 jobs before hitting their 2.5TB limit, and subsequent jobs would remain in “PD” state until running jobs completed.

The maximum number of slots per user may be temporarily increased by submitting a request to bitsupport@lists.jhu.edu. We will increase the limit, depending on the availability of cluster resources. There are also dedicated queues for stakeholders which may have custom configurations and limits.



Schedule

- Introductions – who are we, who are you?
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- Details – limits and resources
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Lab 3



Running R on the cluster:

- In `$HOME/class-scripts/R-demo`, note 2 files – Script file and R file
- Submit Script file
 - `sbatch plot1.sh`
- Run R commands interactively
 - `srun --pty --x11 bash`
 - `module load conda_R`
 - `R --no-save -f plot1.r`
- Look at pdf from example 4 via `xpdf`



Lab 4 – Transferring data

Data can be transferred to and from the cluster via the **transfer node**.

From outside of the JHPCE cluster, you can access the **transfer node** by using the address `jhpce-transfer01.jhsph.edu`. On a Mac or Linux system, you can use the text version of `sftp` to transfer data. You would start by running the following **from your local laptop or desktop**:

```
$ sftp USERID@jhpce-transfer01.jhsph.edu
```

Login with the same credentials used for `ssh`. From within the `sftp` session, you can use `ls` and `cd` commands as well as the `get` command to get a file from the cluster and save it on your local system, and `put` to upload a file from your local system to the cluster.

```
sftp> cd class-scripts/R-demo
sftp> ls
plot1.r plot1-R-results.pdf plot1.r.Rout plot1.sh slurm-1344981.out
sftp> get plot1-R-results.pdf
```

Once you have the file on your laptop, you can look at it with the PDF viewer on your laptop. You can also use graphical `sftp` programs like Cyberduck on Mac or MobaXterm on Windows.

From within the JHPCE cluster, you can access the **transfer node** by running:

```
$ srun --pty --partition=transfer bash
```

This can be used if you need to download large files from the internet or some external source to the JHPCE cluster (`wget`, `curl`, `git clone`).

More info on transferring files on JHPCE can be found at:

<https://jhpce.jhu.edu/access/file-transfer/>

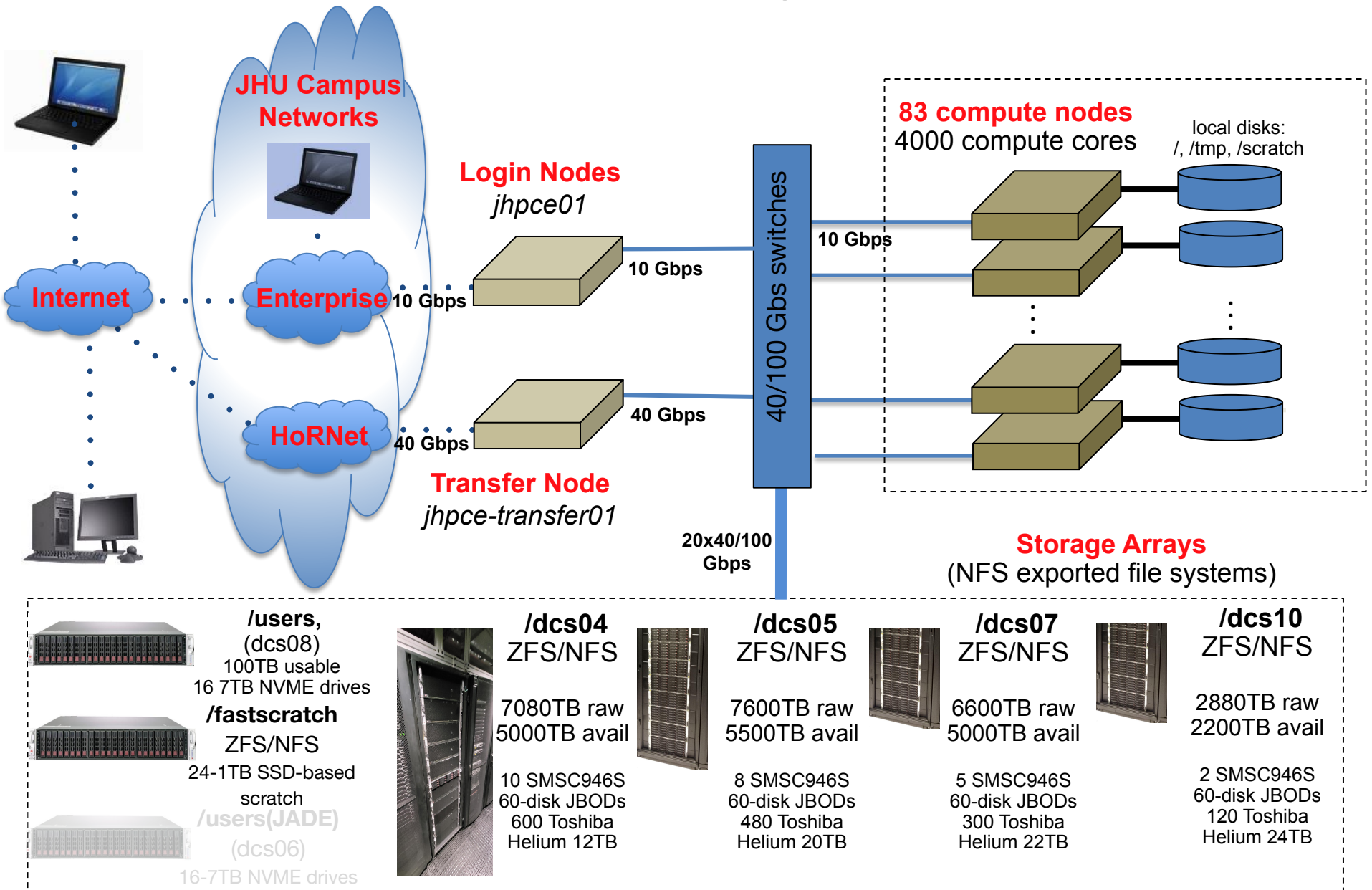
<https://jhpce.jhu.edu/access/mobaxterm/#configuring-sftp-sessions>

<https://www.digitalocean.com/community/tutorials/how-to-use-sftp-to-securely-transfer-files-with-a-remote-server>



Workstations, Desktops, Laptops

JHPCE System Architecture



Lab 5

Running RStudio

- X Windows Setup

- For Windows, MobaXterm has an X server built into it
- For Mac, you need to have the Xquartz program installed (which requires a reboot), and you need to add the "-X" option to ssh:

```
$ ssh -X yourusername@jhpc01.jhsph.edu
```

- Start up Rstudio

```
$ srun --pty --x11 --mem=10G bash  
$ module load conda_R  
$ module load rstudio  
$ rstudio
```

Your `srun` session will be running, but you will not be able to run additional commands until you exit out of `rstudio`.



Lab 6 – Running Stata



Batch:

```
$ cd $HOME/class-scripts/stata-demo
$ ls
$ more stata-demo1.sh # see contents of the batch script
$ more stata-demo1.do # see contents of the stata program
$ sbatch stata-demo1.sh
$ cat stata-demo1.log # see the output
```

Interactive:

```
$ srun --pty --x11 --cpus-per-task=4 bash
$ module load stata
$ stata-mp
```

or

```
$ xstata-mp # starts the GUI interface
```

Notes:

- The program and script do not need to be named the same, but it is good practice to keep them the same when possible.
- File extensions are sometimes meaningful in Linux. SAS doesn't care, but Stata programs need to have ".do" as the extension. It is good practice for human readability.
- By default "stata" runs a single thread. For faster results when running on real data, request 2 or more cores and use the command "stata-mp" instead of "stata"
- By default stata stores temporary files in /tmp. You may need to define an environmental variable to avoid job failure due to lack of space. `export STATATMP=$HOME`



Lab 7 – Running SAS



- SAS example:

Batch:

```
$ cd $HOME/class-scripts/SAS-demo
$ ls
$ more sas-demo1.sh
$ more class-info.sas
$ sbatch --partition=sas sas-demo1.sh
```

Interactive:

```
$ srun --pty --x11 --partition=sas bash
$ module load sas
$ sas
```

To display a plot, SAS needs to send it to a web browser running on the compute node. To do this you would need to run:

```
$ sas -helpbrowser SAS -xrm "SAS.webBrowser:'/usr/bin/chromium-browser'" -xrm
"SAS.helpBrowser:'/usr/bin/chromium-browser'"
```

Since that's a lot to type, you can create a bash function by adding the following lines to your ~/.bashrc file.

```
csas ()
{
    sas -helpbrowser SAS -xrm "SAS.webBrowser:'/usr/bin/chromium-browser'" -xrm
    "SAS.helpBrowser:'/usr/bin/chromium-browser'" "$@" > /dev/null 2>&1
}
```

Once added, and after logging out and back in, you can start sas with its options by just running “csas”.



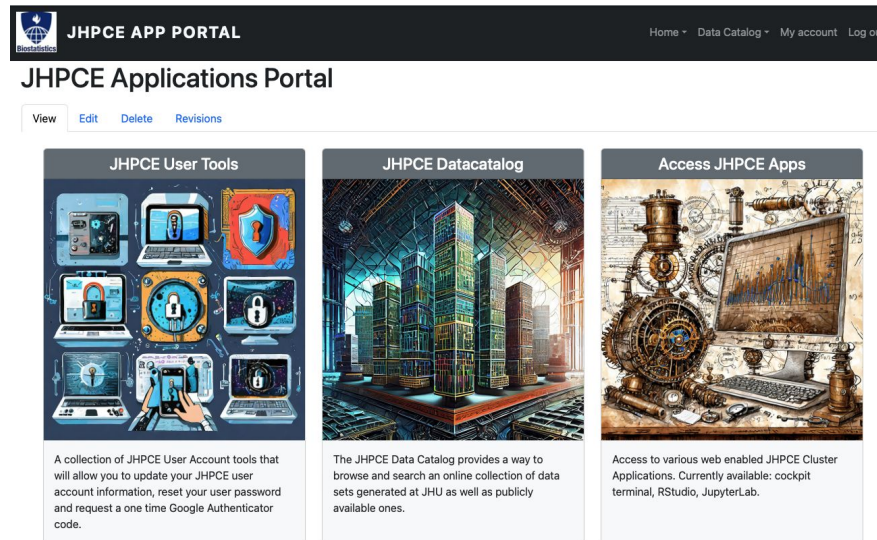
Other Queues/Partitions

- “shared” partition – default queue
- “dedicated” partition - Queues that are for PIs who have purchased nodes on the cluster.
- “transfer” partition
 - `srun --pty --x11 -p transfer bash`
(jhpce-transfer01.jhsph.edu)
- “sas” partition
 - `srun --pty --x11 -p sas bash`
- “gpu” partition
 - `srun --pty --x11 -p gpu --gpus=1 bash`



JHPCE App Portal

You can access the JHPCE App Portal at <https://jhpce-app02.jhsph.edu>



The App Portal can be used for:

- User self service (password resets)
- Access to web-based Apps (Rstudio, Jupyter Labs, Visual Studio)
- Only accessible on campus or via VPN

More information can be found on our web site <https://jhpce.jhu.edu/portal/web-apps/>

Summary

- Review
 - Use ssh to connect to JHPCE cluster
 - Use srun and sbatch to submit jobs or run an interactive session
 - Never run jobs on the login nodes
 - Helpful resources
 - <https://jhpce.jhu.edu> (available anywhere)
 - <https://jhpce-app02.jhsph.edu> (available on campus or VPN)
 - bitsupport@lists.johnshopkins.edu - System issues
 - bithelp@lists.johnshopkins.edu - Application issues
- What to do next
 - Set up ssh keys if you will be accessing the cluster frequently
<https://jhpce.jhu.edu/access/ssh/>
 - Get familiar with Linux
 - Play nice with others – multi-user, community-supported system.



Thanks for attending! Questions?

