Uni.lu HPC School 2019

PS4a: Monitoring & Profiling I

why, what, how, where to look

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http://hpc.uni.lu

Latest versions available on Github:

UL HPC tutorials:	https://github.com/ULHPC/tutorials
UL HPC School:	http://hpc.uni.lu/hpc-school/
PS4a tutorial sources:	ulhpc-tutorials.rtfd.io/en/latest/

Summary

1. Objectives
2. Experiment planning & workflow
3. Hardware knowledge
4. Live status
5. Common mistakes and pitfalls
6. Getting help

Objectives

- Understanding a standard HPC workflow (development and production run)
- Monitoring your job at the system level
- Monitoring your job at the job scheduler level
- Finding your bottlenecks

Summary

1. Objectives
2. **Experiment planning & workflow**
3. Hardware knowledge
4. Live status
5. Common mistakes and pitfalls
6. Getting help

Workflow for Experiment Campaigns

1. Before the campaign
   - Send data to the clusters
   - Check/Install required software
2. Preparation
   - Test and debug
   - Prepare launcher script
3. Execution
   - Run the campaign
   - Monitor the execution
4. After a campaign
   - Retrieve output data
   - Archive and cleanup your data

Experiment campaign: Preparation

Goals

- Make sure everything will run OK
- Prepare submission script / launcher

Interactive approach

- Use the alias `si` to start an interactive job
- Allows to try commands one by one
- Work on a small case with a small number of cores
- Debug and check the results

Why prepare a submission script?

- Contains all commands and parameters
  ⇒ Easy re-execution
- No need to stay in front your computer

Experiment campaign: Execution

Submit the jobs

- Use the submission script / launcher
- Iris: Submit to Slurm with `sbatch your_script.sh` (Slurm batch Script)
- Actual experiment execution with possibly many nodes
- Non interactive execution, it might not start immediately

Get resource usage of your program with time

- `time` tool is installed on the nodes which give execution time of a command or script
- You can use time command to get more info about CPU usage, memory usage, socket messages sent, etc...
- `/usr/bin/time -v ./stress-script.sh`

Experiment campaign: Monitor the execution

- Output/Logfile of your application
- Slurm scheduler information:
  - ↪ List your jobs and statuses: `squeue -u <yourlogin>`
  - ↪ Information of a running job: `sstat -j <jobid>`
  - ↪ Used resources information: `sacct`

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Heterogeneity

- Heterogeneous clusters
- Special nodes (‘bigmem‘, ‘gpu‘)
- Nodes must be targeted explicitely if reproducibility is important (benchmarks, performance evaluation, algorithm comparison, etc)

Heterogeneity (Iris)

Vendor	N	Proc. Description	Cores	Mem
Dell	108	Xeon E5-2680 v4 @ 2.4GHz	2 × 14C	128GB
Dell	60	Xeon Gold 6132 @ 2.6GHz	2 × 14C	128GB
Dell	24	Xeon Gold 6132 @ 2.6GHz	2 × 14C	768GB
		+ 4x NVidia Tesla V100		
Dell	4	Xeon Platinum 8180M @ 2.5 GHz	4 × 28C	3072GB

- sbatch -p batch –qos qos-batch -C broadwell [...]
- sbatch -p batch –qos qos-batch -C skylake [...]
- sbatch -p gpu –qos qos-gpu [...]
- sbatch -p bigmem –qos qos-bigmem [...]

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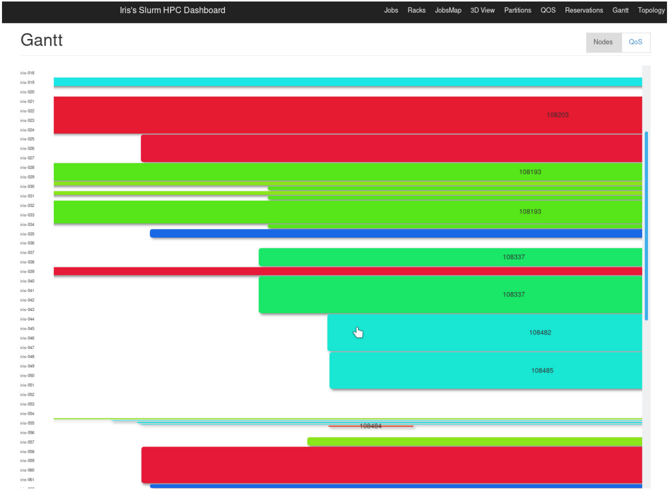
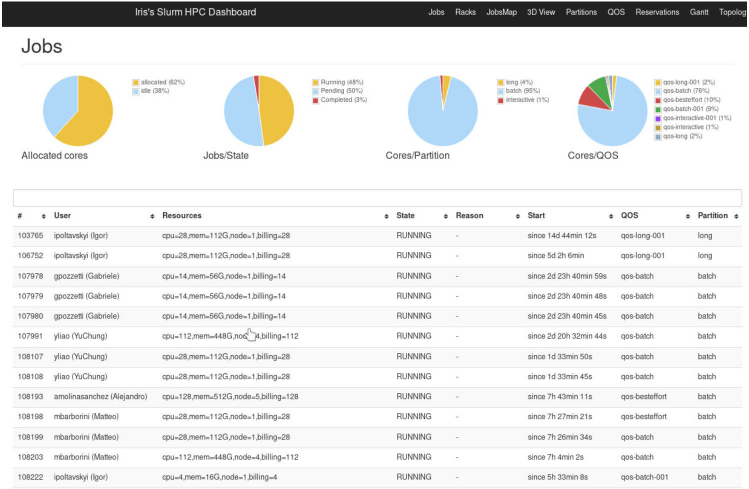
Slurm Web

`https://access-iris.uni.lu/slurm/`



Slurm Web

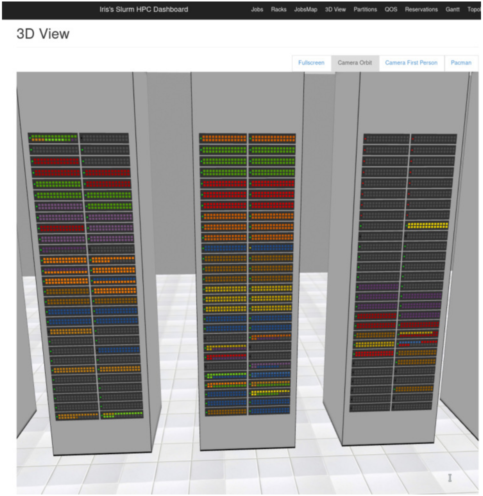
https://access-iris.uni.lu/slurm/



#	User	Resources	State	Reason	Start	QOS	Partition
103765	ipoltavskyi (Igor)	cpu=28,mem=112G,node=1,billing=28	RUNNING	-	since 14d 44min 12s	qos-long-001	long
106752	ipoltavskyi (Igor)	cpu=28,mem=112G,node=1,billing=28	RUNNING	-	since 5d 2h 6min	qos-long-001	long
107978	gpozzetti (Gabriele)	cpu=14,mem=56G,node=1,billing=14	RUNNING	-	since 2d 23h 40min 59s	qos-batch	batch
107979	gpozzetti (Gabriele)	cpu=14,mem=56G,node=1,billing=14	RUNNING	-	since 2d 23h 40min 48s	qos-batch	batch
107980	gpozzetti (Gabriele)	cpu=14,mem=56G,node=1,billing=14	RUNNING	-	since 2d 23h 40min 45s	qos-batch	batch
107991	yliao (YuChung)	cpu=112,mem=448G,node=4,billing=112	RUNNING	-	since 2d 20h 32min 44s	qos-batch	batch
108107	yliao (YuChung)	cpu=28,mem=112G,node=1,billing=28	RUNNING	-	since 1d 33min 50s	qos-batch	batch
108108	yliao (YuChung)	cpu=28,mem=112G,node=1,billing=28	RUNNING	-	since 1d 33min 45s	qos-batch	batch
108193	amolinasanchez (Alejandro)	cpu=128,mem=512G,node=5,billing=128	RUNNING	-	since 7h 43min 11s	qos-besteffort	batch
108198	mbarborini (Matteo)	cpu=28,mem=112G,node=1,billing=28	RUNNING	-	since 7h 27min 21s	qos-besteffort	batch
108199	mbarborini (Matteo)	cpu=28,mem=112G,node=1,billing=28	RUNNING	-	since 7h 26min 34s	qos-batch	batch
108203	mbarborini (Matteo)	cpu=112,mem=448G,node=4,billing=112	RUNNING	-	since 7h 4min 2s	qos-batch	batch
108222	ipoltavskyi (Igor)	cpu=4,mem=16G,node=1,billing=4	RUNNING	-	since 5h 33min 8s	qos-batch-001	batch

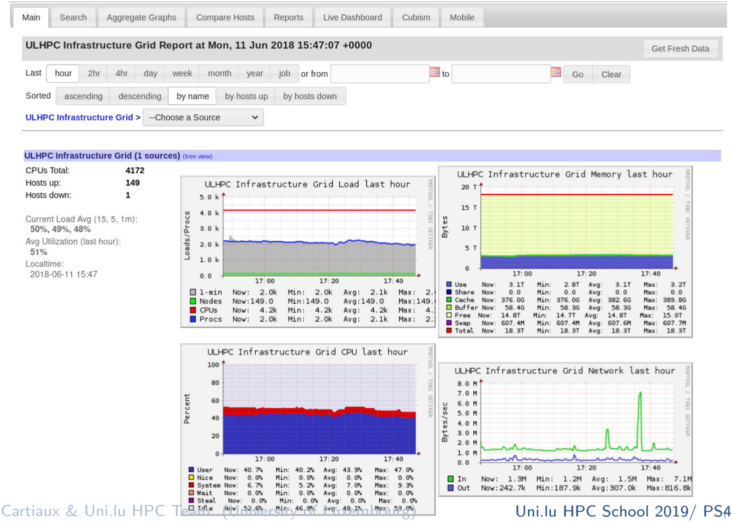
Slurm Web

https://access-iris.uni.lu/slurm/



Resource usage

`http://hpc.uni.lu/iris/ganglia`



ULHPC Infrastructure Grid Report at Mon, 11 Jun 2018 15:47:07 +0000

ULHPC Infrastructure Grid > --Choose a Source

ULHPC Infrastructure Grid (1 sources) (tree view)

CPUs Total:	**4172**
Hosts up:	**149**
Hosts down:	**1**

Current Load Avg (15, 5, 1m):
50%, 49%, 48%

Avg Utilization (last hour):
51%

Localtime:
2018-06-11 15:47

ULHPC Infrastructure Grid Load last hour

```
□ 1-min   Now:  2.0k   Min:  2.0k   Avg:  2.1k   Max:  2.
■ Nodes   Now:149.0    Min:149.0    Avg:149.0    Max:149.
■ CPUs    Now:  4.2k   Min:  4.2k   Avg:  4.2k   Max:  4.
■ Procs   Now:  2.0k   Min:  2.0k   Avg:  2.1k   Max:  2.
```

ULHPC Infrastructure Grid Memory last hour

```
■ Use    Now:   3.1T   Min:   2.8T  Avg:   3.1T   Max:   3.2T
■ Share  Now:   0.0    Min:   0.0   Avg:   0.0    Max:   0.0
■ Cache  Now: 376.0G   Min: 376.0G  Avg: 382.6G   Max: 389.8G
■ Buffer Now:  58.4G   Min:  58.3G  Avg:  58.3G   Max:  58.4G
□ Free  Now:  14.8T   Min:  14.7T  Avg:  14.8T   Max:  15.0T
■ Swap   Now: 607.4M   Min: 607.4M  Avg: 607.6M   Max: 607.7M
■ Total  Now:  18.3T   Min:  18.3T  Avg:  18.3T   Max:  18.3T
```

ULHPC Infrastructure Grid CPU last hour

```
■ User   Now:  40.7%   Min:  40.2%  Avg:  43.9%   Max:  47.0%
■ Nice   Now:   0.0%   Min:   0.0%  Avg:   0.0%   Max:   0.0%
■ System Now:   6.7%   Min:   5.2%  Avg:   7.0%   Max:   9.3%
■ Wait   Now:   0.0%   Min:   0.0%  Avg:   0.0%   Max:   0.0%
■ Steal   Now:   0.0%   Min:   0.0%  Avg:   0.0%   Max:   0.0%
□ Idle   Now:  52.6%   Min:  46.8%  Avg:  49.1%   Max:  53.0%
```

ULHPC Infrastructure Grid Network last hour

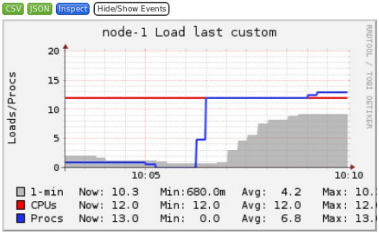
```
■ In     Now:   1.3M   Min:   1.2M  Avg:   1.5M   Max:   7.1M
■ Out    Now:242.7k    Min:187.9k   Avg:307.0k    Max:816.8k
```

Getting faster: Identify performance bottlenecks

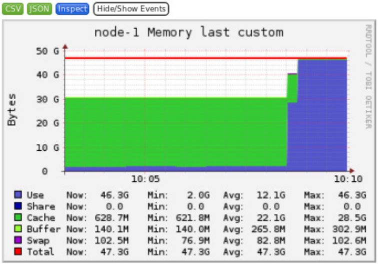
Note for code developers: The first bottleneck is your algorithm!
Know the hardware

- Computer nodes are connected using a fast interconnect
- Different types of resources:
  Processors, GPU, Memory, Storage, Network

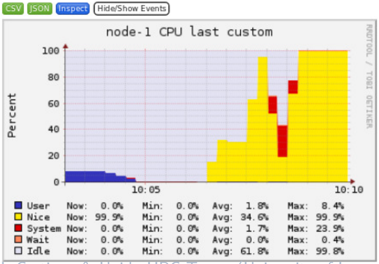
Identify your bottleneck (memory)



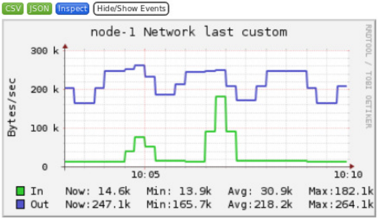
```
□ 1-min   Now: 10.3   Min:680.0m   Avg:  4.2   Max: 10.
■ CPUs    Now: 12.0   Min: 12.0    Avg: 12.0   Max: 12.
■ Procs   Now: 13.0   Min:  0.0    Avg:  6.8   Max: 13.
```



```
■ Use     Now:  46.3G   Min:   2.0G   Avg:  12.1G   Max:  46.3G
■ Share   Now:   0.0    Min:   0.0    Avg:   0.0    Max:   0.0
■ Cache   Now: 628.7M   Min: 621.8M   Avg:  22.1G   Max:  28.5G
■ Buffer  Now: 140.1M   Min: 140.0M   Avg: 265.8M   Max: 302.9M
■ Swap    Now: 102.5M   Min:  76.9M   Avg:  82.8M   Max: 102.6M
■ Total   Now:  47.3G   Min:  47.3G   Avg:  47.3G   Max:  47.3G
```



```
■ User    Now:  0.0%   Min:  0.0%   Avg:  1.8%   Max:  8.4%
■ Nice    Now: 99.9%   Min:  0.0%   Avg: 34.6%   Max: 99.9%
■ System  Now:  0.0%   Min:  0.0%   Avg:  1.7%   Max: 23.9%
■ Wait    Now:  0.0%   Min:  0.0%   Avg:  0.0%   Max:  0.4%
□ Idle    Now:  0.0%   Min:  0.0%   Avg: 61.8%   Max: 99.8%
```



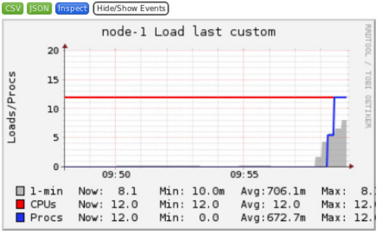
```
■ In    Now: 14.6k   Min: 13.9k   Avg: 30.9k   Max:182.1k
■ Out   Now:247.1k   Min:165.7k   Avg:218.2k   Max:264.1k
```

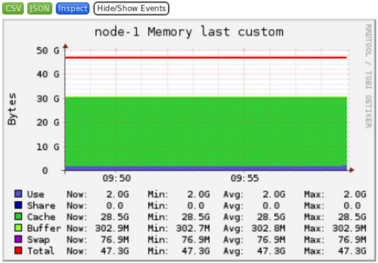
Identify your bottleneck (memory)

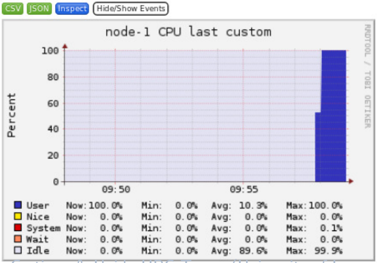
Application is limited by the size of the memory

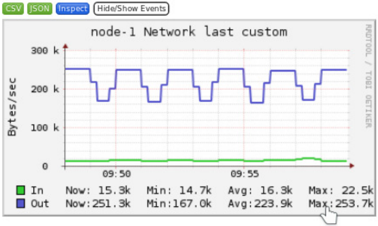
- Reserve all CPUs on a single node, to get access to all memory banks
- Use a node with a bigger memory (bigmem)
- Distributed execution on multiple nodes (MPI)

Identify your bottleneck (CPU)







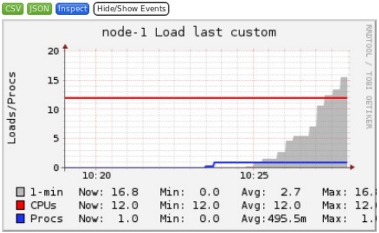


Identify your bottleneck (CPU)

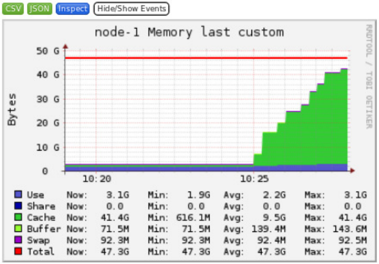
Application is limited by the speed of the processor

- Optimize your code
- Use GPU accelerator (CUDA)
- Parallel execution on multiple nodes (MPI)
- Parallel execution on multiple nodes with GPUs (MPI+CUDA)

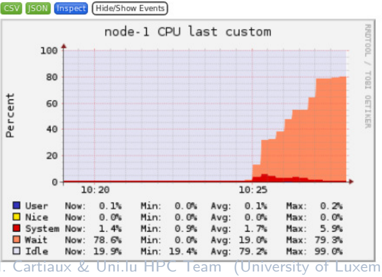
Identify your bottleneck (I/O)



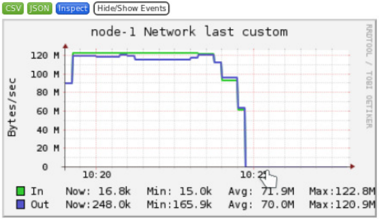
```
■ 1-min   Now: 16.8    Min:  0.0    Avg:   2.7    Max: 16.
■ CPUs    Now: 12.0    Min: 12.0    Avg:  12.0    Max: 12.
■ Procs   Now:  1.0    Min:  0.0    Avg:495.5m    Max:  1.
```



```
■ Use    Now:  3.1G   Min:   1.9G   Avg:   2.2G   Max:   3.1G
■ Share  Now:  0.0    Min:   0.0    Avg:   0.0    Max:   0.0
■ Cache  Now: 41.4G   Min: 616.1M   Avg:   9.5G   Max:  41.4G
■ Buffer Now: 71.5M   Min:  71.5M   Avg: 139.4M   Max: 143.6M
■ Swap   Now: 92.3M   Min:  92.3M   Avg:  92.4M   Max:  92.5M
■ Total  Now: 47.3G   Min:  47.3G   Avg:  47.3G   Max:  47.3G
```



```
■ User   Now:  0.1%   Min:  0.0%   Avg:  0.1%   Max:  0.2%
■ Nice   Now:  0.0%   Min:  0.0%   Avg:  0.0%   Max:  0.0%
■ System Now:  1.4%   Min:  0.9%   Avg:  1.7%   Max:  5.9%
■ Wait   Now: 78.6%   Min:  0.0%   Avg: 19.0%   Max: 79.3%
■ Idle   Now: 19.9%   Min: 19.4%   Avg: 79.2%   Max: 99.0%
```



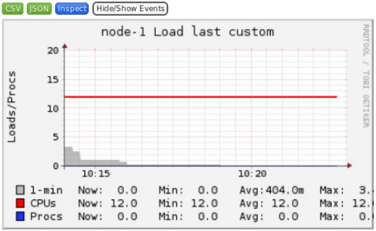
```
■ In    Now: 16.8k    Min: 15.0k    Avg: 71.9M    Max:122.8M
■ Out   Now:248.0k    Min:165.9k    Avg: 70.0M    Max:120.9M
```

Identify your bottleneck (I/O)

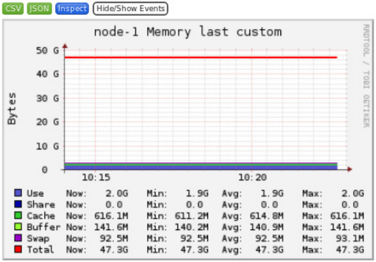
Application is limited by the speed of the storage

- Use local storage, eg `/tmp`, instead of network storage
- Use local memory, eg `/dev/shm`
- Use $SCRATCH (no backup)

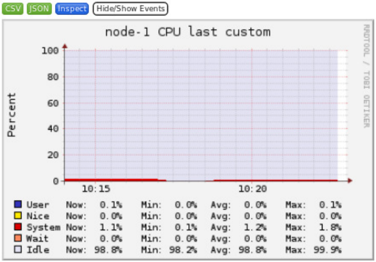
Identify your bottleneck (Network)



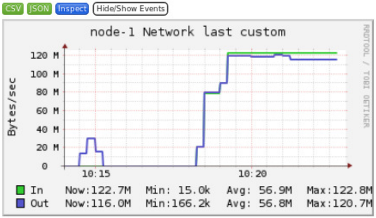
```
□ 1-min   Now:  0.0   Min:  0.0   Avg:404.0m   Max:  3.
■ CPUs    Now: 12.0   Min: 12.0   Avg: 12.0    Max: 12.
■ Procs   Now:  0.0   Min:  0.0   Avg:  0.0    Max:  0.
```



```
■ Use     Now:   2.0G   Min:   1.9G   Avg:   1.9G   Max:   2.0G
■ Share   Now:   0.0    Min:   0.0    Avg:   0.0    Max:   0.0
■ Cache   Now: 616.1M   Min: 611.2M   Avg: 614.8M   Max: 616.1M
■ Buffer  Now: 141.6M   Min: 140.2M   Avg: 140.9M   Max: 141.6M
■ Swap    Now:  92.5M   Min:  92.5M   Avg:  92.5M   Max:  93.1M
■ Total   Now:  47.3G   Min:  47.3G   Avg:  47.3G   Max:  47.3G
```



```
■ User    Now:  0.1%   Min:  0.0%   Avg:  0.0%   Max:  0.1%
■ Nice    Now:  0.0%   Min:  0.0%   Avg:  0.0%   Max:  0.0%
■ System  Now:  1.1%   Min:  0.1%   Avg:  1.2%   Max:  1.8%
■ Wait    Now:  0.0%   Min:  0.0%   Avg:  0.0%   Max:  0.0%
□ Idle    Now: 98.8%   Min: 98.2%   Avg: 98.8%   Max: 99.9%
```



```
■ In    Now:122.7M   Min: 15.0k   Avg: 56.9M   Max:122.8M
■ Out   Now:116.0M   Min:166.2k   Avg: 56.8M   Max:120.7M
```

Identify your bottleneck (Network)

Application is limited by the speed of the network (too many communications)

- Use Infiniband instead of Ethernet
- Reduce the number of nodes

Command line tools

Connect to the node during your passive job

- SLURM: `srun -jobid <jobid> -pty bash`

- memory usage: `free -m`
- list current processes and statistics: `ps aux`
- processes ordered by CPU usage: `top`
- like top, but interactive: `htop`
- filesystem usage: `df-ulhpc`
- live system statistics (including I/O and network): `dstat`

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Common pitfalls

My job has been terminated, why ?

1. Maximum memory usage exceeded
   - ↪ The Linux *Out Of Memory Killer* (OOMK) mechanism killed your processes silently.
   - ↪ The available memory depends on the number of cores/CPUs reserved
   - ↪ Use the parameter `-mem-per-cpu` with srun
2. Requested walltime exceeded
   - ↪ The walltime specified with your submission command (sbatch, srun) was too short
   - ↪ Your job walltime cannot be extended after its submission
   - ↪ The job duration must be estimated before its submission
   - ↪ Use the parameter `-time` with srun

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6 **Getting help**

Know the basics!

Access the clusters, access and reserve nodes

- Use SSH and public key authentication
  `https://hpc.uni.lu/users/docs/access.html`
- Learn how to use the SLURM batch scheduler (Iris cluster only)
  `https://hpc.uni.lu/users/docs/slurm.html`

Transfer files between your computer and the clusters

- Learn how to use tools like `scp`, `rsync`, etc.
  `https://hpc.uni.lu/users/docs/filetransfer.html`

Use pre-installed software

- Search and use software with the `module` command
  `https://hpc.uni.lu/users/docs/modules.html`

In this order

1. Check the UL HPC quick reference
   `https://hpc.uni.lu/download/documents/ulhpc-quickref.pdf`
2. Read The Fine Manual at `https://hpc.uni.lu/docs`
3. `$ man man`
4. Google is your friend!
5. Open a ticket on
   `hpc-tracker.uni.lu`
6. Ask the HPC sysadmins
   `hpc-sysadmins@uni.lu`
7. Bonus: ask the users community mailing list
   `hpc-users@uni.lu`

Thank you for your attention...

Questions?

http://hpc.uni.lu

High Performance Computing @ uni.lu

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