ECE 574 – Cluster Computing
Lecture 4

Vince Weaver

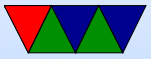
http://web.eece.maine.edu/~vweaver

vincent.weaver@maine.edu

26 January 2023

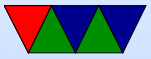
Announcements

- Homework #2 will be posted
- Got the Haswell-EP machine set up again

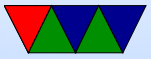


Sever Account Info

- Log in to weaver-lab. Be sure to use port 2131 or it will try to connect to the wrong machine. (Why?)
- Change your password first thing.
- Behave. No hacking/cracking/spamming/irc-bots/bitcoing-mining
  Also be responsible with disk usage, as I don't have disk quota set up.
- Also the disk isn't backed up so be careful when deleting files

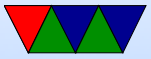


- If you find a security bug, great! Let me know! Don't go deleting things or impersonating people or installing root kits, or other stuff.

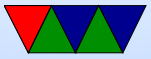


Speedup / Parallel Efficiency Examples

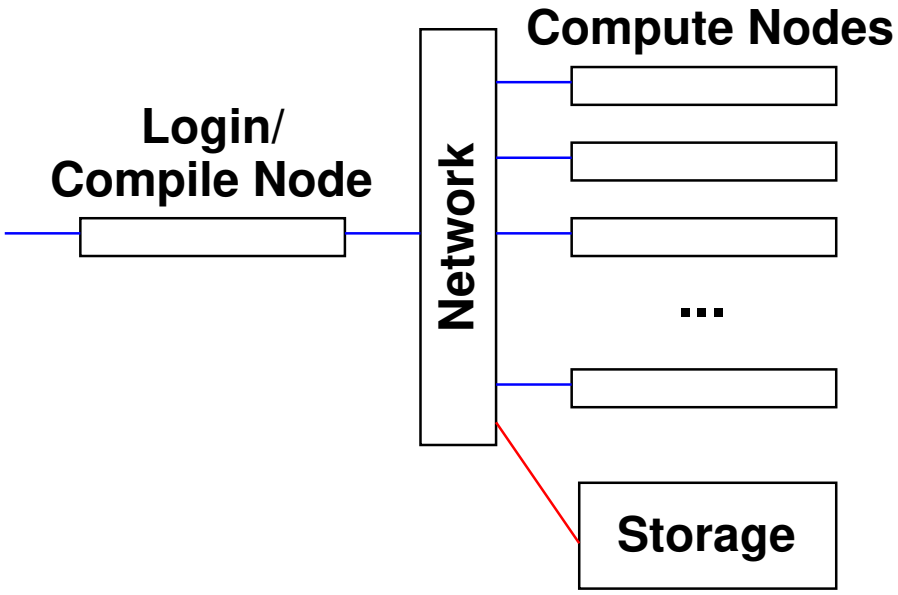
- Reminder
  - Speedup $= S_p = \frac{T_s}{T_p}$
    where p=# of processes (threads)
    $T_s =$ execution time of sequential code
    $T_p =$ execution time of parallel with p processes
    For ideal, $S_p = p$
  - Parallel Efficiency
    $E_p = \frac{S_p}{p} = \frac{T_s}{pT_p}$
    Ideal linear speedup E_p=1



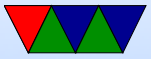
- Examples where serial code takes 120s, p=2
  - $T_2 = 150s,\ S_p = \frac{120}{150} = 0.8, E_p = \frac{.8}{2} = .4$
  - $T_2 = 120s,\ S_p = \frac{120}{120} = 1, E_p = \frac{1}{2} = .5$
  - $T_2 = 60s,\ S_p = \frac{120}{60} = 2, E_p = \frac{2}{2} = 1$
  - $T_2 = 30s,\ S_p = \frac{120}{30} = 4, E_p = \frac{4}{2} = 2$



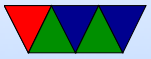
Commodity Cluster Setup



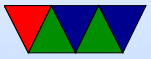
- Simple cluster like the pi-cluster, or older ones I've made
- Commodity cluster design is a combo of ECE331/ECE435 more than anything else



- Why have a head node?
- What kind of network? Ethernet? Inifiniband? Something fancier?
- Operating system? Do all nodes need a copy of the OS? Linux? Windows? None?
- Booting: network boot, local disk boot.
- Network topology? Star? Direct-connect? Cube? Hyper-cube?
- Disk: often shared network filesystem. Why? Simple: NFS (network file system). More advanced cluster filesystems available.

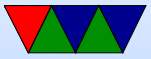


- Don't forget power/cooling
- Running software?

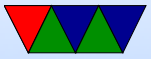


Job Schedulers

- On a big cluster, how do you submit jobs?
- If everyone just logged in to nodes at random, would be a mess
- Batch job scheduling
- Different queues (high priority, long running, etc)
- Resource management (make sure don't over commit, use too much RAM, etc)
- Notify you when finished?
- Accounting (how much time used per user, who is going

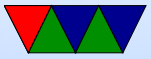


to pay?)

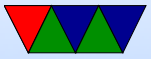


Scheduling

- Different Queues Possible – Low priority? Normal? High priority (paper deadline)? Friends/Family?
- FIFO – first in, first out
- Backfill – bypass the FIFO to try to efficiently use any remaining space
- Resources – how long can run before being killed, how many CPUs, how much RAM, how much power? etc.

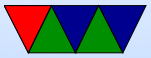


- Heterogeneous Resources – not all nodes have to be same. Some more cores, some older processors, some GPUs, etc.



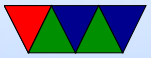
Common Job Schedulers

- PBS (Portable Batch System) – OpenPBS/PBSPro/TORQ
- nbs
- slurm
- moab
- condor
- many others



Slurm

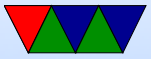
- `http://slurm.schedmd.com/`
- Slurm Workload Manager
  Simple Linux Utility for Resource Management
  Futurama Joke?
- Developed originally at LLNL
- Over 60% of top 500 use it



sinfo

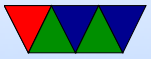
provides info on the cluster

```
PARTITION AVAIL  TIMELIMIT  NODES  STATE NODELIST
debug        up   infinite      1   idle haswell-ep
general*     up   infinite      1   idle haswell-ep
```



`srun`

start a job, but interactively



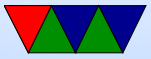
sbatch

submit job to job queue

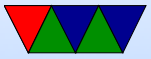
```
#!/bin/bash

#SBATCH -p general        # partition (queue)
#SBATCH -N 1                # number of nodes
#SBATCH -n 8                # number of cores
#SBATCH -t 0-2:00         # time (D-HH:MM)
#SBATCH -o slurm.%N.%j.out # STDOUT
#SBATCH -e slurm.%N.%j.err # STDERR
export OMP_NUM_THREADS=4
./xhpl
```

Notes: `sbatch -N 24 - -ntasks-per-node=4 ./time_`

To run on all 96 cores of pi-cluster

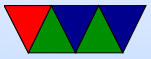


Can set up to e-mail you when done (though only locally).



squeue

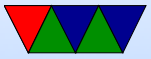
```
JOBID PARTITION     NAME     USER ST       TIME  NODES NODELIST(REASON)
   63   general time_hpl ece574-0 PD       0:00      1 (Resources)
   64   general time_hpl ece574-0 PD       0:00      1 (Resources)
   65   general time_hpl ece574-0 PD       0:00      1 (Resources)
   62   general time_hpl ece574-0  R       0:14      1 haswell-ep
```



scancel

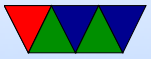
kills job

```
scancel 65
```



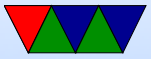
Running Linpack

- HPL solves linear system of equations, Ax=b. LU factorization.
- Download and install a BLAS. ATLAS? OpenBLAS? Intel?
  Compiler? intel? gcc? gfortran?
- Download and install MPI (we'll talk about that later). MPICH? OpenMPI?
- Download HPL. Current version 2.3?
  Modify a Makefile (not trivial) make sure links to proper

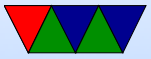


BLAS. make arch=OpenBLAS

- Above step, might need to create a link from hpl in your home directory to actual location for reasons
- Create a a bin/OpenBLAS with default HPL.dat file
- Run it `./xhpl` Or if on cluster `./mpirun -np 4 ./xhpl` or similar.
- Result won't be very good. Need to tune HPL.dat
- N is problem size. In general want this to fill RAM. Take RAM size, squareroot, round down. NxN matrix. Each N is 8 bytes for double precision.
- NB block size, can be tuned

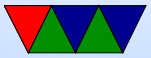


- PxQ, if on cluster can specify machine grid to work on. Linpack works best with as square as possible.
- Fiddle with all the results until you get the highest.



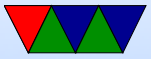
Linpack Results on my Lab Computers

- https://web.eece.maine.edu/~vweaver/group/machi
  html
- Selecfion of Machines
  - haswell-ep: 436 GFLOPS, 16/32 cores, 80GB, 2.13GFLOP/W
  - power8: 195 GFLOPS, 8/64 cores, 32GB
  - M1 ARM Mac laptop: 154 GFLOPS, 6 GFLOPS/W
  - pi-cluster: 15.4 GFLOPS, 96 cores, 24GB RAM, 0.166 GFLOP/W



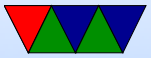
- pi-4 2.02 GFLOPS/W

- First top500 list, June 1993. Top machine 1024 cores, 60 GFLOPS, 131kW
  Pi cluster would have been #7
- I ran HPCG benchmark on Haswell-EP machine.
  Theoretical: 16DP FLOP/cycle * 16 cores * 2.6GHz = 666 GFLOPS
  Linpack/OpenBLAS: 436 GFLOPS (65% of peak),
  HPCG: 0.7 GFLOPS (0.1% of peak)



Live Demo

- Logging in
- Linpack
- “time”
- perf
  - perf stat
  - perf list
  - perf record
  - perf report
  - perf annoate



- system status
  - w
  - top
  - htop
- slurm
  - sinfo
  - squeue
  - sbatch