Linux Clusters: Details and Case Studies

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What is your situation?

- Who are the users?
- What application(s) will they run?
- Faster turnaroud or higher throughput?
- How much am I willing to spend?
- Where can I put the machines?
- Who can administer the machines?

User Rules of Thumb

- 1-4 users:
  - Yes, you still want a queueing system.
  - Plan ahead to avoid idle time and conflicts.
- 5-20 users:
  - Put one person in charge of running things.
  - Work out a fair-share or reservation system.
- > 20 users:
  - User documentation and examples are essential.
  - Decide who makes resource allocation decisions.

Application Rules of Thumb

- 1-2 programs:
  - Don't pay for anything you won't use.
  - Benchmark, benchmark, benchmark!
    - Be sure to use your typical data.
    - Try different compilers and compiler options.
- > 2 programs:
  - Select the most standard OS environment.
  - Benchmark those that will run the most.
    - Consider a specialized cluster for dominant apps only.

Parallelization Rules of Thumb

- Throughput is easy…app runs as is.
- Turnaround is not:
  - Parallel speedup is limited by:
    - Time spent in non-parallel code.
    - Time spent waiting for data from the network.
  - Improve serial performance first:
    - Profile to find most time-consuming functions.
    - Try new algorithms, libraries, hand tuning.

Budget Rules of Thumb

- $2K to $20K: Desktop PCs on shelves, 24-port gigabit switch, $700/CPU.
- $20K to $50K: Dual-CPU rackmount, 24-port gigabit switch, $1000/CPU.
- > $50K:
  - Single large gigabit cluster for throughput.
  - Myrinet or Infiniband for turnaround, $2000/CPU.
  - Consider multiple 24-node gigabit clusters.

Environment Rules of Thumb

- 12 CPUs per 20A 110V circuit
  - In a rack, 24 CPUs per 20A 208V circuit
- 20 CPUs per ton of air conditioning

- Buy a Kill-A-Watt for $30 and measure!
  - Watts = Amps * Volts * Power Factor
  - Run something intense like “cpuburn”:
    - Nodes draw 50% more current under load.
    - Poorly cooled or unstable machines crash!

SysAdmin Rules of Thumb

- Automate everything you can:
  - Small differences are a pain to debug.
  - Use install/setup scripts for the head node too.
- Limit root access:
  - A little knowledge is a dangerous thing.
  - Have one or two trusted backup admins.
  - In a medical emergency you call 911 and follow instructions until the paramedics arrive, right?
  - Post numbers call in an emergency. A call at 3am is better than finding a broken cluster at 9am.

Some Details Matter More

- What limiting factor do you hit first?
  - Budget?
  - Space, power, and cooling?
  - Network speed?
  - Memory speed?
  - Processor speed?
  - Expertise?

Limited by Budget

- Don't waste money solving problems you can't afford to have right now:
  - Regular PCs on shelves (rolling carts)
  - Gigabit networking and multiple jobs
- Benchmark performance per dollar.
  - The last dollar you spend should be on whatever improves your performance.
- Ask for equipment funds in proposals!

Limited by Space

- Benchmark performance per rack
- Consider all combinations of:
  - Rackmount nodes
    - More expensive but no performance loss
  - Dual-processor nodes
    - Less memory bandwidth per processor
  - Dual-core processors
    - Less memory bandwidth per core

Extreme Space Issues

- Blade servers
  - Proprietary and expensive
- Cooling integrated into the rack
  - CSE Turing cluster uses these
  - Expensive
  - Requires plumbing
  - Makes me nervous

Limited by Power/Cooling

- Benchmark performance per Watt
- Consider:
  - Opteron or PowerPC rather than Xeon
  - Dual-processor nodes
  - Dual-core processors

Extreme Power Issues

- Orion Multisystems deskside cluster
  - Proprietary and expensive
  - 96 Transmeta processors draw 15A
    - 1/8 the power of a normal CPU
    - 1/3 the performance of normal CPU
    - Must scale better to run at same speed
    - Same performance per Watt from dual core?
  - www.orionmulti.com

Limited by Network Speed

- Benchmark your code at NCSA.
  - 10,000 CPU-hours is easy to get.
  - Try running one process per node.
    - If that works, buy single-processor nodes.
  - Try Myrinet.
    - If that works, can you run at NCSA?
  - Can you run more, smaller jobs?

Extreme Network Issues

- Three main choices:
  - Myrinet…proprietary but well established
  - Infiniband…multi-vendor but new
  - 10 Gigabit Ethernet…very new
- Consider
  - Fewer nodes with more CPUs/cores
  - The opinions of those with experience

Limited by Serial Performance

- Is it memory performance? Try:
  - Single-core Opterons
  - Single-processor nodes
  - Larger cache CPUs
  - Lower clock speed CPUs
- Is it really the processor itself? Try:
  - Higher clock speed CPUs
  - Dual-core CPUs

Limited by Expertise

- There is no substitute for a local expert.

- Qualifications:
  - Comfortable with the Unix command line.
  - Comfortable with Linux administration.
  - Cluster experience if you can get it.

Install It Yourself

- Don’t use the vendor’s pre-loaded OS.
  - They would love to sell you 100 licenses.
  - What happens when you have to reinstall?
  - Do you like talking to tech support?
  - Are those flashy graphics really useful?
  - How many security holes are there?

Purchasing Tips: Before You Begin

- Get your budget
- Work out the space, power, and cooling capacities of the room.
- Start talking to vendors early
  - But don't commit!
- Don't fall in love with any one vendor until you've looked at them all.

Purchasing Tips: Design Notes

- Make sure to order some spare nodes
  - Serial nodes and hot-swap spares
  - Keep them running to make sure they work.
- If possible, install HDs only in head node
  - State law and UIUC policy requires all hard drives to be wiped before disposal
  - It doesn't matter if the drive never stored anything!
  - Each drive will take 8-10 hours to wipe.
    - Save yourself a world of pain in a few years…
    - …or just give your machines to some other campus group, and make them worry about it.

Purchasing Tips: Get Local Service

- If a node dies, do you want to ship it?
- Two choices:
  - Local business (Champaign Computer)
  - Major vendor (Sun)
- Ask others about responsiveness.
- Design your cluster so that you can still run jobs if a couple of nodes are down.

Purchasing Tips: Dealing with Purchasing

- You will want to put the cluster order on a Purchase Order (PO)
  - Do not pay for the cluster until it entirely works.
- Prepare a ten-point letter
  - Necessary for all purchases >$25k.
  - Examples are available with your business office (or bug us for our examples).
  - These aren't difficult to write, but will probably be necessary.

Purchasing Tips: The Bid Process

- Any purchase >$28k must go up for bid
  - Exception: sole-source vendors
  - Number grows every year
  - Adds a month or so to the purchase time
  - If you can keep the numbers below the magic $28k, do it!
    - The bid limit may be leverage for vendors to drop their prices just below the limit; plan accordingly.
- You will get lots of junk bids
  - Be very specific about your requirements to keep them away!

Purchasing Tips: Working the Bid Process

- Use sole-source vendors where possible.
  - This is a major reason why we buy from Sun.
  - Check with your purchasing people.
  - This won't help you get around the month time loss, as the item still has to be posted.
- Purchase your clusters in small chunks
  - Only works if you're looking at a relatively small cluster.
  - Again, you may be able to use this as leverage with your vendor to lower their prices.

Purchasing Tips: Receiving Your Equipment

- Let Receiving know that the machines are coming.
  - It will take up a lot of space on the loading dock.
  - Working with them to save space will earn you good will (and faster turnaround).
  - Take your machines out of their space as soon as reasonably possible.

Purchasing Tips: Consolidated Inventory

- Try to convince your Inventory workers to tag each cluster, and not each machine
  - It's really going to be running as a cluster anyway (right?).
  - This will make life easier on you.
    - Repairs are easier when you don't have to worry about inventory stickers
  - This will make life easier for them.
    - 3 items to track instead of 72

Purchasing Tips: Assembly

- Get extra help for assembly
  - It's reasonably fun work
    - …as long as the assembly line goes fast.
  - Demand pizza.
- Test the assembly instructions before you begin
  - Nothing is more annoying than having to realign all of the rails after they're all screwed in.

Purchasing Tips: Testing and Benchmarking

- Test the cluster before you put it into production!
  - Sample jobs + cpuburn
  - Look at power consumption
  - Test for dead nodes
- Remember: vendors lie!
  - Even their demo applications may not work; check for yourself.

Security Tips

- Restrict physical access to the cluster, if possible.
  - Make sure you're involved in all tours, to make sure nobody touches anything.
- If you're on campus, put your clusters into the Fully Closed network group
  - Might cause some limitations if you're trying to submit from off-site
  - Will cause problems with GLOBUS
  - The built-in firewall is your friend!

Case Studies

- The best way to illustrate cluster design is to look at how somebody else has done it.
  - The TCB Group has designed four separate Linux clusters in the last six years

2001 Case Study

- Users:
  - Many researchers with MD simulations
  - Need to supplement time on supercomputers
- Application:
  - Not memory-bound, runs well on IA32
  - Scales to 32 CPUs with 100Mbps Ethernet
  - Scales to 100+ CPUs with Myrinet

2001 Case Study 2

- Budget:
  - Initially $20K, eventually grew to $100K
- Environment:
  - Full machine room, slowly clear out space
  - Under-utilized 12kVA UPS, staff electrician
  - 3 ton chilled water air conditioner (Liebert)

2001 Case Study 3

- Hardware:
  - Fastest AMD Athon CPUs available (1333 MHz).
  - Fast CL2 SDRAM, but not DDR.
  - Switched 100Mbps Ethernet, Intel EEPro cards.
  - Small 40 GB hard drives and CD-ROMs.
- System Software:
  - Scyld clusters of 32 machines, 1 job/cluster.
  - Existing DQS, NIS, NFS, etc. infrastructure.

2003 Case Study

- What changed since 2001:
  - 50% increase in processor speed
  - 50% increase in NAMD serial performance
  - Improved stability of SMP Linux kernel
  - Inexpensive gigabit cards and 24-port switches
  - Nearly full machine room and power supply
  - Popularity of compact form factor cases
  - Emphasis on interactive MD of small systems

2003 Case Study 2

- Budget:
  - Initially $65K, eventually grew to ~$100K
- Environment:
  - Same general machine room environment
  - Additional machine room space is available in server room
    - Just switched to using rack-mount equipment
  - Still using the old clusters; don't want to get rid of them entirely
    - Need to be more space-conscious

2003 Case Sudy 3

- Option #1:
  - Single processor, small form factor nodes.
  - Hyperthreaded Pentium 4 processors.
  - 32 bit 33 MHz gigabit network cards.
  - 24 port gigabit switch (24-processor clusters).
- Problems:
  - No ECC memory.
  - Limited network performance.
  - Too small for next-generation video cards.

2003 Case Study 4

- Final decision:
  - Dual Athlon MP 2600+ in normal cases.
    - No hard drives or CD-ROMs.
    - 64 bit 66 MHz gigabit network cards.
  - 24 port gigabit switch (48-proc clusters).
  - Clustermatic OS, boot slaves off of floppy.
    - Floppies have proven very unreliable, especially when left in the drives.
- Benefits:
  - Server class hardware w/ ECC memory.
  - Maximum processor count for large simulations.
  - Maximum network bandwidth for small simulations.

2003 Case Study 5

- Athlon clusters from 2001 recycled:
  - 36 nodes outfitted as desktops
    - Added video cards, hard drives, extra RAM
    - Cost: ~$300/machine
    - Now dead or in 16-node Condor test cluster
  - 32 nodes donated to another group
  - Remaining nodes move to server room
    - 16-node Clustermatic cluster (used by guests)
    - 12 spares and build/test boxes for developers

2004 Case Study

- What changed since 2003:
  - Technologically, not much!
  - Space is more of an issue.
  - A new machine room has been built for us.
  - Vendors are desperate to sell systems at any price.

2004 Case Study 2

- Budget:
  - Initially ~$130K, eventually grew to ~$180K
- Environment:
  - New machine room will store the new clusters.
  - Two five-ton Liebert air conditioners have been installed.
  - There is minimal floor space, enough for four racks of equipment.

2004 Case Study 3

- Final decision:
  - 72x Sun V60x rack-mount servers.
    - Dual 3.06GHz Intel processors – only slightly faster
    - 2GB RAM, Dual 36GB HDs, DVD-ROM included in deal
    - Network-bootable gigabit ethernet built in
    - Significantly more stable than any old cluster machine
  - 3x 24 port gigabit switch (3x 48-processor clusters)
  - 6x serial nodes (identical to above, also serve as spares)
  - Sun Rack 900-38
    - 26 systems per rack, plus switch and UPS for head nodes
  - Clustermatic 4 on RedHat 9

2004 Case Study 4

- Benefits:
  - Improved stability over old clusters.
  - Management is significantly easier with Sun servers than PC whiteboxes.
  - Network booting of slaves allows lights-off management.
  - Systems use up minimal floor space.
  - Similar performance to 2003 allows all 6 clusters (3 old + 3 new) to take jobs from a single queue.
  - Less likely to run out of memory when running an “express queue” job.
  - Complete machines easily retasked.