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 turnaround 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
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 Infiniband or 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
AMD vs Intel Processors

Core 1
L1
L2
Crossbar
Memory Controller
Memory

Core 2
L1
L2
Crossbar

Core 1
L1
L2
Crossbar

Core 2
L1
Memory Controller
Memory
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 Athlon 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 Study 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.