Performance analysis for parallel applications

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Outline

- **Parallel vs. distributed computing**
- **Specific performance problems**
  - using MPI or OpenMP
  - some parallel tools
- **RQCHP: the HPC network**
- **DRAP laboratory**
- **Developer's remarks**

Parallel vs. distributed computing

- Parallel systems:
  - Often SPMD programs:
    - using OpenMP or MPI
  - Real-time performance:
    - dedicated nodes
      - No workload sharing
    - 1-to-1 mapping
      - (Processor,Thread)

- Distributed systems :
  - Often MPMD programs:
    - client-server, P2P, …
  - …

Using MPI and OpenMP standards

- Message passing interface
  - data distribution and task scheduling:
    - controlled by developer
  - explicit communications
  - often predictable

- Open Multiprocessing
  - shared memory and fork/join model:
    - synchronized by developer
  - implicit communications
  - … less predictable
    - Memory access ?

Some MPI performance problems

- Point-to-point communication

• Late sender	Idle receiver waiting for message
• Late receiver	Idle (blocked?) sender

- Collective communication

• Late broacast/scatter	Root not ready to send
• Early reduce /gather	Waiting for non-root

- Any I/O: MPI-IO, PVFS, database ?

MPI perf analysis tools

- tracing
    - MPE/Jumpshot, Trace Collector/Analyzer, KOJAK
- profiling
    - TAU, mpiP, hpcprof
  - many tools use
    - PAPI, PMPI, DynInst

Now OpenMP performance problems

- Load Imbalance
  - In parallel section Work per thr. or # of thr.
  - In parallel loop Iterations (wait, no wait)
- Synchronization, parallel control
  - Contention in critical section Competing threads
  - Serialization Parallel loop with critical section
  - Bad scheduling Loop overhead
  - False sharing Overhead to get same cache line

OpenMP perf analysis tools

- tracing
    - Thread Checker, OPARI
- profiling
    - TAU, Thread Profiler, ompP

OpenMP performance analysis

- Quick (and cheap) look :
  - use hardware counters to identify problems
- Identify region and search the cause:
  - true/false sharing invalidations
  - coherence misses (?)

« Performance of a multiprocessor depends on the performance of the system when sharing data. »
Hennessy & Patterson, Computer Architecture, IV ed., MK(2007)

Cache coherence problems

- Detect coherence miss:
  - access data that was in the proc.cache previously, but was invalidated by a write from another proc.
  - Not for hardware counter !
- SMP cache simulator: **ccSIM** (Rsim, SimOS...)
  - Huge tracing files: online compression (LZO, ...)

    « Source-code-correlated cache coherence characterization of OpenMP benchmarks »
    Marathe & Mueller, IEEE TPDS, vol. 18, pp. 818-834 (2007)

RQCHP: HPC network

http://rqchp.ca

- researchers from:
  - Universités: de Montréal, de Sherbrooke, Concirdia, Bishop, École Polytechnique,
  - FCI funding

RQCHP: HPC network

http://rqchp.ca

- **Mammouth (Mp)** @ Université de Sherbrooke
  - Most powerful supercomputer in Canada
  - Dell 1425SC: 576 nodes dual-Xeon - 8 GB mem
  - Network interface (communication)   InfiniBand
- **Altix 4700** @ Université de Montréal
  - SGI 384 nodes dual-Itanium II - 4 GB mem
  - Shared memory image: NUMAlink

RQCHP: HPC network

http://rqchp.ca

- Analysts use tools :
  - **gprof** GNU/tool
  - **pfmon** HP dev.
  - **pgprof** Portland gr.
  - **histx** SGI
  - Trace Analyzer (ex-Vampir)

- plus, for debug:
  - **gdb**, **pgdb**, **idb**
  - **Totalview**

- and monitoring
  - **ganglia**

Altix 4700 – common problems

- Code run well with small #(proc)
  - Automatic parallelization, etc.

- When #(proc) is increased, be aware of:
  - any memory leak
    - TotalView or MemoryScape can help
  - cache coherency misses
  - doing too much I/O

The DRAP laboratory

http://www.polymtl.ca/drap

- Design and Realization of Parallel Applications
  - Parallel codes:
    - DRAGON/DONJON codes (nuclear engineering)
      - Varin, Dahmani, He
    - LBM and DEM codes (chemical engineering)
      - Leclaire, Vidal
  - Tools for parallel systems:
    - **AdélieLinux**
    - **Clone+Napalm**
    - ..and other projects: MPI2XML, PolyJob

AdélieLinux

- Idea:
  - diskless node – get OS by network (Adélie/SSI)
  - with optimized parallel tools (Adélie/HPC)
- Single-system image
  - integrated in Gentoo distr. (32 & 64-bit versions)
  - limits: scalability, I/O

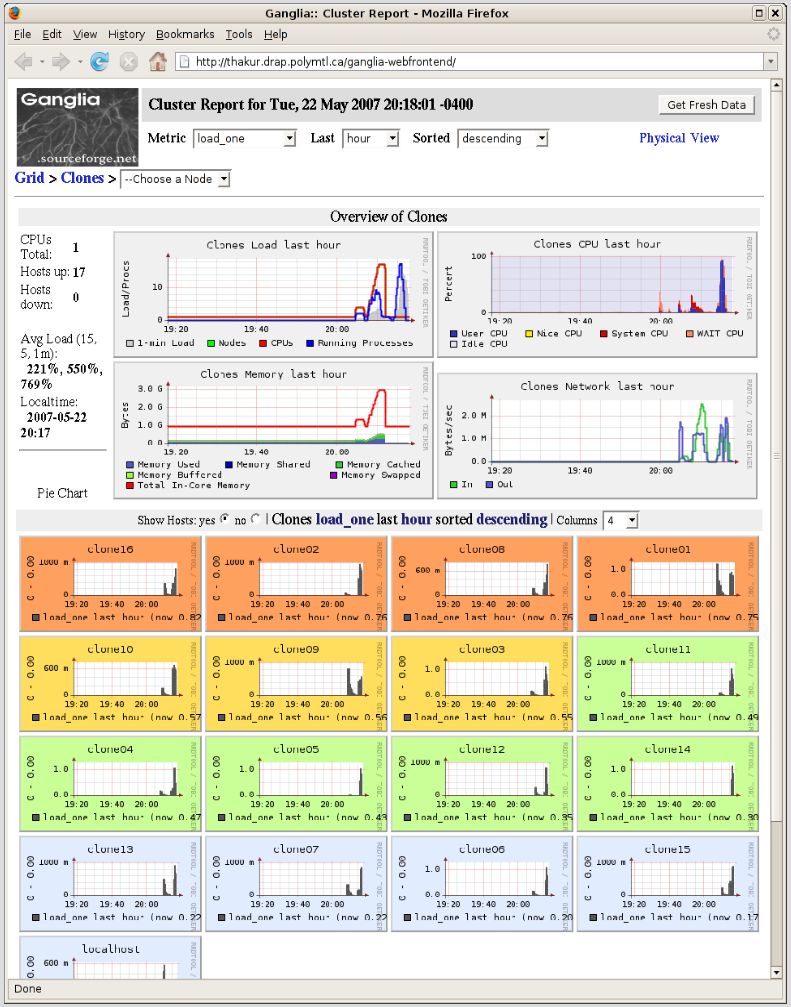
- **Benoît Morin, B.Ing.,M.Sc.A., now working at IREQ**

Clone+Napalm

- Idea:
  - light virtual nodes – boot/transfer OS clones
  - coupling virtualization (Xen) and UnionFS
- Single-filesystem image
  - transferring kernel and early-userspace module
  - using initramfs under Genkernel

- **Jean-François Richard, B.Ing., M.Sc.A., now in Norway**

Clone+Napalm



http://thakur.drap.polymtl.ca/ganglia-webfrontend/

Cluster Report for Tue, 22 May 2007 20:18:01 -0400

Metric load_one Last hour Sorted descending

Grid > Clones > --Choose a Node

CPUs Total: 1
Hosts up: 17
Hosts down: 0

Avg Load (15, 5, 1m): 221%, 550%, 769%

Localtime: 2007-05-22 20:17

Show Hosts: yes ● no ○ | Clones load_one last hour sorted descending | Columns 4

- Heartbeat & monitoring of clones:
  - gmond
  - gmetad
    - XML data
  - ganglia

Clone+Napalm

- Performance of user-level programs:
  - Processor-bound   No virtualization overhead
  - Network (netperf)   No visible overhead
    - (here only1 clone <=>1 NIC)
      - www.vmware.com/pdf//Multi-VM_Network_Performance.pdf
  - I/O   10-15% overhead
    - Most overhead is from UnionFS

Steps in performance analysis

- instrumentation/measurement
  - source, wrapper library, binary
  - hardware counters, trace points
  - must ensure:
    - correctness, scalability
- analysis
  - online, automatic, post-mortem
  - timeline diagrams, charts, metric panels, source code

Developer's remarks

- usability:
  - less work to do => most likely to use the tool !
    - clear documentation, quick start, tutorial
- efficiency:
  - Is tool any better than ad-hoc techniques ?
  - Does tool help to find performance problem ?
  - Is tool able to analyze and find it ? ... solve it ?

My bucket list

- Tracing/profiling in the VMM:
  - anyone remembers **SIMMON** ?
    - http://en.wikipedia.org/wiki/SIMMON
- Parallel analysis of trace files:
  - next generation **Vampir** ?