Exaflop Computing : Visions and Challenges: A thousand times better, not just for the High End

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panel discussion at the International Symposium of Parallel and Distributed Processing and Applications, Sydney, 2008

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1 Exaflop vs Exascale Computing

- Exascale Computing: aim by 2015 to:
  - $1000\times$ RoadRunner performance: 1.6 petaflops, LINPACK (exaflops)
  - $1\times$ RoadRunner performance at $1/1000\times$ energy
  - $1000\times$ 'better' on smaller scales
- the crucial challenge, in terms of power/performance: (Peter Kogge)
  - not in the flops, but the cost to move data
  - from RAM to CPU chip, across networks
- are there other dimensions to 'better'?
  - productivity (HPCS):programming, usability (+security)
    - models: dedicated system, batch supercomputer, super-cluster / cloud
  - reliability

These only increase the challenge . . .

2 Exascale Systems

- dramatic improvements in performance / energy will hardware specialized for the key applications
  - processing: (hetero-) multicore, GPU, FGPA
  - FGPA and standard network processors / interfaces
    - the QPACE QCD architecture (Goldrian et al, 2008)
- hence heterogeneity will also need to be handled
- need hierarchy (architecture, run-time environment, algorithms) to minimize long-range data transfers
- need also programming paradigms that can handle these
  - a forerunner: the Liquid Metal project (Huang, Horman, Bacon and Rabbath, 2006)
- challenge: can all this be done with the right level of abstraction (performance and robustness vs. productivity)

3 Virtualization in Exascale Computing

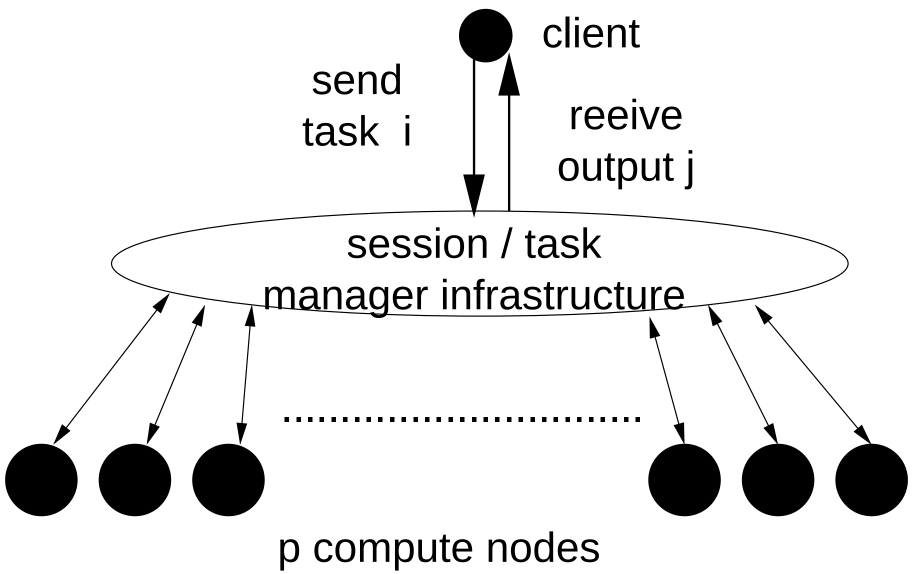
- virtualization allows users to customize their environments
- also allows for easy migration across super-cluster / cloud
  - move parallel job to more suitable parts of heterogeneous system as they become available
  - move job closer to its (possibly varying) data sources
- interesting forerunner: Snowflock Project (U. Toronto, 2008)
  - 'fork' a Xen VM to achieve parallelism; surprisingly low overhead
  - current motivation: cloud computing (biosciences)
- extra performance overheads still to be addressed (e.g. heterogeneous multicore)

4 Programming Paradigms: Productivity and Reliability

- MPI has been long denounced wrt. productivity (e.g. Thomas Sterling, Cluster'04)
  - worst still under the assumption of heterogeneity
- alternatives such as cluster-aware OpenMP have difficulties achieving comparable (even satisfactory) performance
- some reasons (page-based software DSM systems):
  - granularity of communications; pages often too small
  - difficulty to fetch in advance, use collective communications
  - simply parallelizing loops in existing algorithms may be sub-optimal
- neither model can easily be made reliable against node failures
  - (distributed) processor state is hard to save
  - typically alleviated by explicit checkpointing
- do the HPCS languages address this any better?

5 Lessons from the Grid: Fault-Tolerance, Heterogeneity-oblivious, Programmability

- frameworks for large sets of embarrassingly parallel tasks
  - e.g. Symphony middleware (for 'coarse' tasks on enterprise grids) (Platform (TM) Computing)



- task i: receives input, performs local computation, sends output
- naturally load balancing if number of tasks $>> p$
- fault-tolerance: if a compute node fails, simply restart its task

- can we extend this model for general parallel computation?
  - with use of a smart FT 'fabric' to hold/cache/move global data