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

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1 Exaflop vs Exascale Computing

- Exascale Computing: aim by 2015 to:
  - $1000 \times \text{RoadRunner performance: 1.6 petaflops, LINPACK (exaflops)}$
  - $1 \times \text{RoadRunner performance at } 1/1000 \times \text{energy}$
  - $1000 \times \text{‘better’ on smaller scales}$

- the crucial challenge, in terms of power/performance: (Peter Kogge)
  - not in the \textit{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

- 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

- 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-oblivioues, 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