HPC System Software Vision for Exascale Computing and Beyond

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April 23, 2014

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What is Exascale

• Today
  – Tianhe-2 (Milkyway-2)
    – 54 Peak PF
    – 125 racks, 17.8 MW, 48K Phis, 3.1M cores
  – K computer 10PF 800 racks, Sequoia 20 PF 100 racks

• Exascale
  – $10^{18}$ operations per second
  – Biggest challenges: Power, Scalability, Reliability
    – Approximate straight-line projections yield:
      – 350M Watts
      – 100M computing threads
      – Each OS instance needs to stay up 50,000 years
  – Biggest change: I/O
    – Bits can no longer traverse from spinning disk to registers and back
  – Software approaches need to address these challenges
PEZ
Exascale is only a point on the continuum

Zeta
Exa
Peta
When investigations began
- Challenges too great with current SW
- Need all new OS, compiler, language...

Others advocated
- Enhance capability of existing
- Hard, drive evolutionary approach
Revolutionary versus Evolutionary

- Which one?
Imagine vendors telling their customers to throw out everything you’ve done over the last 20+ years. Leverage tremendous investment in Intel Architecture ecosystem.
Evolutionary Only

But there are serious challenges getting to exascale. Drive new innovations and invigorate the x86 ecosystem.
The real challenge in moving software to extreme scale, and therefore the real solution, will be figuring out how to incorporate and support existing computation paradigms in an evolutionary model while simultaneously supporting new revolutionary paradigms.
Moving to Extreme Scale

• Support evolutionary and revolutionary models

• Scale

• Be resilient

• Be power aware
Communication Example

Application

Extensible Communication and Composable Runtime Layer

Software Hardware Interface Labels

Hardware

ER  MPI  OpenMP  Charm++  ParalleX  PGAS
Operating System Example

- Linux
- Ap
- High Perf API
- Common API
- Implementation

- K42
- Hypervisor
- LibraOS
- ExOS
OS Compute Node View

- CNOS that fully supports Linux API and ABI
- Nimble to support new technology effectively
- Move to hierarchy of OS offload for scalability
- Support fine-grained threading and asynchronous requests
- Provide support for and be amenable to running on differentiated cores
Data Management for Big Data
(Long-Term View Active Short-Term Work)

- Smooth representation between
  - Application data structure in memory
  - Representation and access to NVRAM
  - External access
  - Storage to disk
- Moving compute to data

```c
main() A[100][100][100];
graph_node {
  int value;
  edge e1;
}
```
Glass Half Full

• You want revolution?
  – You got it!

• You want your own revolution?
  – You got it!

• You want our revolution?
  – You got it!
Transition Path Through PEZY

- Applications can move at the pace they need as dictated by their code

- Researchers have framework to insert research into
  - Runtimes
  - Libraries
  - Execution environments

- Existing infrastructure continues to work and evolve
Conclusion

- We will get to extreme scale (PEZ) by figuring out how to incorporate existing computation paradigms in an *evolutionary* model while *simultaneously* supporting new *revolutionary* paradigms
  - Support evolutionary and revolutionary models
  - Scale
  - Be resilient
  - Be power aware
Backup

- Backup
• Four Pillars of RAS
  – Gather: As extensive as possible, consistent format
  – Store: Database for searching and associating
  – Access: Real-time pub-sub access by all components
  – Process: Agents aggregate, trigger, notify, filter, etc.
System Management

- Provide single comprehensive view of system
- Hierarchical and scalable
- Resilient
Technical Computing Continues Its Rapid Growth

Governments & Research
- The Human Brain Project
- “My goal is simple. It is complete understanding of the universe, why it is as it is and why it exists at all”
  - Stephen Hawking

Commercial/Industrial
- Better Products
- Faster Time to Market
- Reduced R&D

Business Transformation
- Genomics Clinical Information
- From Diagnosis to personalized treatment quickly

New Users – New Uses
- Big Data Analytics
- Enabling Data Driven Science

Fundamental Discovery to Gain Fundamental Insights

HPC: Transforming the world of data and information into KNOWLEDGE

Source: IDC: Worldwide Technical Computing Server 2013–2017 Forecast; Other brands, names, and images are the property of their respective owners.