The Race Has Began. Who will be there first?

The Road to Exascale Computing

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Roadmap

- High Performance Computing in a Nutshell
- Radical Changes in HPC
- The Roadmap of HPC
- Challenges of the Exascale Computing
- Call for Research
- HPC in Egypt
High Performance Computing
in a Nutshell

- What’s the HPC?
- Supercomputers
- Fastest Supercomputer
- Contributions of HPC
- HPC Community

High Performance Computing

- HPC is the field of computer science utilizing aggregated compute capabilities of supercomputers solving advanced computational problems related to other fields of science, such as earth sciences, material sciences, chemistry, biology, or physics.
Supercomputers

- Custom built machines with special specifications:
  - Large system wide memory (100s of terabytes)
  - Advanced processors: multiple processors, each of multiple cores
  - Large Storage: in Petabytes
  - High Speed Low Latency Network: 100 GB/s
  - High utilization % in relatively short periods

Second Fastest Supercomputer

- **Name**: Jaguar
- **Location**: Oak Ridge National Labs, Tennessee, USA
- **Compute Nodes**: 16,688
- **Number of Processors**: 33,376
- **Number of Cores #**: 200,256
- **Memory**: 360 Tera Bytes
- **Storage**: 10 Peta Bytes
- **Processing Power**: 1,750 teraflops (1.75 Petaflops)

#1 is in China with 2.5 PFLOPS
Contributions of HPC

- Building New Materials
  - Simulating different structures and material responses to the surrounding environment.
- Fluid Mechanics
  - New aircrafts, missiles, etc.
- Designing New Drugs
  - Simulating different chemical reactions and how proteins inside our cells interact with these drugs.

Contributions of HPC (Cont’d)

- Simulating Natural Phenomena and Predicting the Future
  - Climate Modeling
  - Space Expansion and the Dark Matter
- Bioinformatics
  - Searching for a matching genes
- Nuclear Physics
  - Simulating nuclear reactions before doing the experiment
Following the HPC Community

- Top500.org
- Green500.org
- US National Labs
  - Argonne, Oak Ridge, Berkeley, Los Almos, North Western, ...
- InsideHPC.com
  - It will take you everywhere
- Twitter.com
  - InsideHPC, IBM, Intel, ORNL, ..... 
- Conferences
  - IPDPS, ICPP, HPCC, HiPC, ..... 
- Podcasts
  - NCSA Videos on demand, Intel Chip Chat, IBM podcasts, Cray, ...
- HPC books collections are expected at AUC library by next Spring

Radical Changes in HPC

- Disruptive Multi-Core Technologies
- New Models of HPC on Demand – Scientific Clouds
- Politics in Sciences
Disruptive Multi-Core Technologies

- Multi-core processors are already 8 years old, but
  
  ……
- Disruptive candidates are jumping into the HPC arena ….. They are Graphics Processing Units (GPUs)
- What’s the big deal here
  - A single graphics card is capable of performing 2.75 TFLOP/s – 50 times the best Intel Xeon processor
  - It costs around $500 to buy this card
  - It consumes only 1.5 times more power compared to CPUs
  - You can learn how to program them in less than 3 months
- So……..
  - The fastest supercomputer is now in China and built of NVIDIA GPUs – 2.5 PFLOPS (2.5 x 10^16 FLOPS/s)
  - The USA is planning to have their next supercomputer capable of 10 PFLOPS by 2012
    - Again using GPUs

HPC on Demand

- Cloud computing: is Internet-based computing, whereby shared resources, software, and information are provided to computers and other devices on demand, as with the electricity grid (Wikipedia)
- If HPC hardware is expensive and not 100% utilized most of the time, why we don’t let others use it.
- Many vendors are jumping in
  - Pioneered by Amazon
    - 2 Tesla GPU with 25 GB of RAM, 1.5 Tbyte HD would cost you $2.7 per CPU hour!
  - Google, Microsoft, and others are following
- So…..
  - You can perform HPC research and get results with few hundreds of dollars
  - You can start immediately with no H/W, administrators, power bill, or maintenance.
  - HPC is now be available for the common researchers
Politics in Science – China!

- Most of the Scientists in the US were shacked when China announced early in November the fastest supercomputer.
- Implications
  - Heating up competition in H/W, S/W, and services
  - HPC community is shooting for the Exascale in 2018 instead of 2020
- The Good News
  - Engineers & Scientists working in HPC are more expensive and difficult to find 😊

The Roadmap of HPC

- Exascale Computing
  - Building the Next Generation of Supercomputers & HPC ecosystem
- The International Exascale Software Project (IESP)
  - http://www.exascale.org
Past to Future

Petascale Systems

Exascale Systems

Terascale Systems

11/1996
- Sandia National Labs
- Conventional CPUs

11/2008
- Los Alamos National Labs
- Conventional CPUs & Cell B.E. Processor

Expected 2020
- Europe, USA, & China are racing!
- Heterogeneous Architectures, i.e. CPUs, GPUs, FPGAs, etc.

Roadmap to the Exascale Computing

- The X-Stack Components
- H/W for the Exascale
- System Software
- Development Environments
- Applications
- Cross-Cutting Dimensions
The X-Stack Components

Hardware for the Exascale

- Low power heterogeneous many-core processors
  - Check the latest GPU, named Echelon, from NVIDIA
    - 10 TFLOPs, 1,024 cores per processor,
- Advanced Vector Extensions
  - Check Intel’s Advanced Vector Extensions Technology (AVX)
    - 256 & 512-bits vector set (64 Integers or floats in one vector)
- Networking
  - UCSB promised 1 TB network by 2016
- Storage
  - SSD ...
- Memory
  - DDRX ...
System Software

- **Operating Systems**
  - Effective management and scheduling policies and mechanisms
- **Run-time Systems**
  - Matches the requirements of the algorithms to the system's available resources.
- **I/O Systems**
  - Proper exposure and management of I/O systems
- **Systems Management**
  - Resources control and scheduling, security, integration and test, logging and reporting, external coordination of resources
- **External Environments**
  - Remote computational resources

Operating Systems

- Taking control again of threads management and control
- A hybrid approach of building brand new operating systems while keeping the current ones doing a decent job
- Innovation is required in:
  - Fault tolerant/masking strategies for collective OS services
  - Strategies and mechanisms for power/energy management
  - Strategies for simulating full-scale systems
  - General strategies for global (collective) OS services
Development Environments

- **Programming Models**
  - Abstract system resources to make programming easier without scarifying performance.

- **Frameworks**
  - Provide a common collection of interfaces, tools, and capabilities

- **Compilers**
  - Implement the programming model

- **Numerical Libraries**
  - Abstract some problems in reusable libraries, i.e. matrix multiplication, FFT, etc.

- **Debuggers**
  - Discovering errors in program code faster

Applications

- **Algorithms**
  - Not likely to change a lot, but must be re-implemented to deal with the realities in an exascale system.

- **Application Support: Data Analysis and Visualization**
  - Making sense of huge data collections
Cross-Cutting Dimensions

- **Resilience**
  - Most probably we will have some failing threads or processors in a machine consists of millions of cores. Should we restart execution?

- **Power Management**
  - Reduction of power consumption is a serious issue: cost, cooling, and the environment (check the green500.org website)

- **Performance Optimization**
  - Engineering, visualization, and optimizing your systems

- **Programmability**
  - How easy and fast can we build applications for these architectures?

Hungry for more?

- Check the Exascale Project’s Roadmap document – very visionary
  - Summarized in my blog [http://MohamedFAhmed.wordpress.com]:
Call for Research

- Possible Areas of Research at the AUC
  - **Computer Science**
    - Performance Engineering
    - Cloud Computing for the HPC
    - Creating New Programming Models
    - Creating New Run-time Models
      - GPU Fusion Project
      - Micro-Threading Model
  - **Computer Engineering**
    - Building FPGA based Terascale processor
    - Building supercomputers out of low power simple pipeline processors
    - Eliminating the PCI bottleneck inside GPUs.

Recap

- High Performance Computing
  - Acceleration Scientific Discovery & Research
- Radical Changes in HPC
  - Many-core architecture
- The Roadmap of HPC
  - Exascale Systems by 2020
- Challenges of the Exascale Computing
  - International Exascale Software Project
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Extra Slides
HPC in Egypt

- We are lacking the application area
  - Most scientists in Egypt rely on experimental research.
  - The road is long to change such perspective
- We don’t have serious barriers building decent supercomputers using commodity hardware, but
  - HPC works in an ecosystem composed of:
    ▪ Challenging scientific problems
    ▪ Capable computer scientists and engineers
    ▪ Well trained administrators
    ▪ Government or funding organizations awareness
    ▪ Industry or execution bodies that would benefit from HPC outputs.

How Can We Start in Egypt

- Raising awareness of Computational Sciences
- Experiment with some toy HPC systems
- Find a direct link between HPC offerings and problems facing our nation
  - Health: diagnosis and drugs design
  - Water Sources: Where most of our water goes
  - Agriculture: What do we have implanted this year.
  - Traffic: simulating traffic to find hotspots and schedule roads flows.
Thanks for your Interest!