China HPC development in the 13th 5-year plan

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Outline

- Current status
- Problems
- Planed efforts

Current status

The 863 key project on HPC

- High Productivity Computer and Application Service Environment (2011-2016)
  - Developing world-class computer systems
    - Tianhe-2
    - Sunway-NG
  - Exploring new operation models and mechanisms for CNGrid
  - Developing cloud-like application villages over CNGrid to promote applications

First phase of TH-2

- Delivered in May 2013
- Hybrid system
  - 32000 Xeon, 48000Xeon Phis, 4096 FT CPUs
- 54.9PF peak, 33.86PF Linpack
- Interconnect
  - proprietary TH Express-2
- 1.4PB memory, 12PB disk
- Power: 17.8MW
- Installed at the National Supercomputing Center in Guangzhou

Second phase of TH-2

- The implementation scheme of the second phase of TH-2 was evaluated and approved in July of 2014
  - Upgrading interconnect (completed)
  - Increasing No. of computing nodes (completed)
  - Upgrading computing nodes
    - Upgrade the accelerator from Knight Conner to Knight Landing
    - Change the ratio of CPU to MIC from 2:3 to 2:2

Second phase of TH-2 (cont'd)

- The scheme has to be changed because of the new embargo regulation of the US government
- Completion of the second phase will be delayed
- The final TH-2 has to rely on indigenous FT processors, a stimulation to the R&D on kernel technologies in China
- The development of the new FT processors is on going

The second 100PF system

- The second 100PF system (Sunway) will be delivered by the end of 2016
- A large system implemented with indigenous SW many-core processors in together with a smaller multicore system (1PF) implemented with commercial processors
  - meet the requirement of different applications
- The development of Sunway goes smoothly

HPC environment development

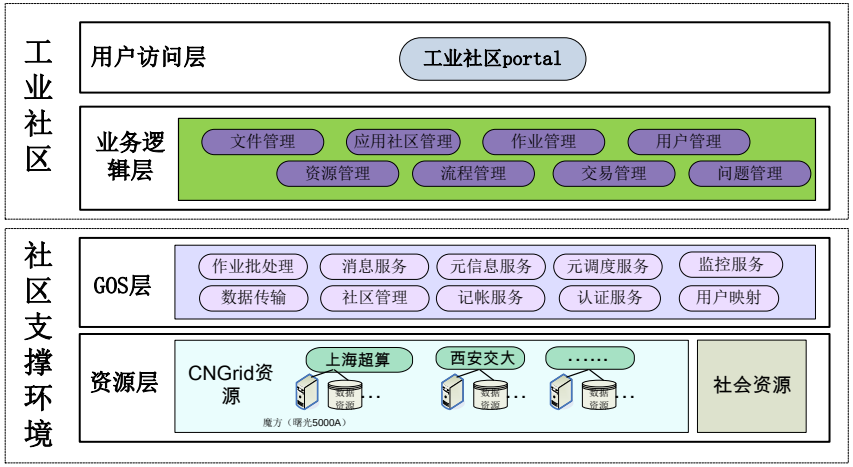
- CNGrid service environment, emphasizing service features
  - enabled by CNGrid Suite
  - 14 nodes
  - 8PF aggregated computing power
  - >15PB storage
  - >400 software and tools as services
  - supporting >1000 projects

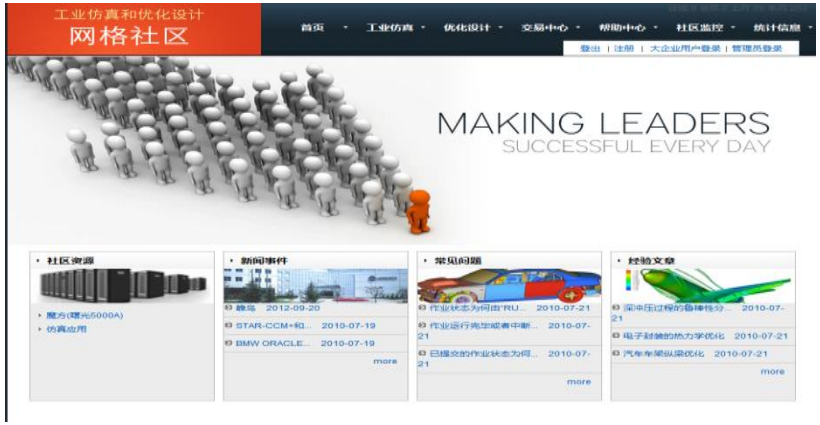
CNGrid sites

	CPU/GPU	Storage
SCCAS	157TF/300TF	1.4PB
SSC	200TF	600TB
NSC-TJ	1PF/3.7PF	2PB
NSC-SZ	716TF/1.3PF	9.2PB
NSC-JN	1.1PF	2PB
THU	104TF/64TF	1PB
IAPCM	40TF	80TB
USTC	10TF	50TB
XJTU	5TF	50TB
SIAT	30TF/200TF	1PB
HKU	23TF/7.7TF	130TB
SDU	10TF	50TB
HUST	3TF	22TB
GPCC	13TF/28TF	40TB

Application villages over CNGrid

- CNGrid is treated as a layer of virtual resources available to the up-layers
- Establishing domain-oriented application villages (communities) on top of CNGrid, which provide services to the end users
- Developing business models and operation mechanisms between CNGrid and application villages
- Developing enabling technologies and platform supporting CNGrid transformation
- Application villages currently being developed
  - Industrial product design optimization
  - New drug discovery
  - Digital media





Parallel software development

- Application software development supported
  - Fusion simulation
  - CFD for aircraft design
  - Drug discovery
  - Rendering for Digital media
  - Structural mechanics for large machinery
  - Simulation of electro-magnetic environment
- Level of Parallelism required
  - Effective use of more 300,000 cores with >30% efficiency
- Must be productive systems in the real applications

Problems

Weakness

- Weakness in kernel technologies
  - processor/accelerator (not available because of the US government regulation)
  - novel devices (new memory, storage, and network)
  - large scale parallel algorithms and programs
  - system software
- Weak in applications
  - rely on imported commercial software
    - expensive
    - small scale parallelism
    - limited by regulation
- Shortage in talents
  - talents with both domain and computing knowledgies
- Lack of cross-disciplinary cooperation

Need an eco-system

- We need an eco-system for HPC development in China
  - Need cooperation of supercomputer developers, application software developer, HPC infrastructure operators, and the end users
  - Need system software, tools, and application software for domestically developed processors
  - Need collaborative work by people from basic research, key technology and system development, and application development

Planed efforts

The new research system

- Five tracks in the new national research system
  - Basic research program
  - Mega-research program
  - Key research and development program
  - Enterprises-oriented research program
  - Research centers and talents program

New key project on HPC

- Strategic studies have been conducted jointly by the 863 key project and the Supercomputing Innovation Alliance under the guidance of the MoST
- A proposal for track-3 key project on HPC in the 13th five-year plan has been submitted and approved in 2015
- The key project has been launched in Feb. 2016

Motivations for the new key project

- The key value of developing Exa-scale computers identified
  - Addressing the grand challenge problems
    - Energy shortage, pollution, climate change…
  - Enabling industry transformation
    - simulation and optimization for important systems and products
      - high speed train, aircraft, and automobile…
    - support economy transformation
  - Social development and people's benefit
    - drug discovery, precision medicine, digital media…
  - Scientific discovery
    - high energy physics, computational chemistry, new material, cosmology…
- Promote computer industry by technology transfer
- Self-controllable HPC technologies
  - A lesson learnt from the recent embargo regulation

Goals and major tasks

- Goals
  - Strengthen development of kernel technologies
  - Pursuing the leading position in high performance computer development
  - Promote HPC applications
  - Build up HPC infrastructure with service features and explore the path to the HPC service industry
- Major tasks
  - Next generation supercomputer development
  - CNGrid upgrading and transformation
  - Domain HPC applications development

1. Development of exa-scale computer

- **Major tasks**
  - R&D on novel architectures and key technologies of the next generation supercomputers
  - Development of an exa-scale computer based on domestic processors
  - Technology transfer to promote development of high-end servers

1. Development of exa-scale computer

- Basic research
  - Novel high performance interconnect
    - Research on theories and implementation technologies of the novel interconnect
      - Based on the enabling technologies of 3-D chip packaging, silicon photonics and on-chip networks
  - New programming models
    - Developing new programming models for heterogeneous computers
      - ease in writing programs
      - exploitation of performance of the heterogeneous architectures

1. Development of exa-scale computer

- Key technology
  - Prototype systems for verification of the exa-scale computer technologies
    - possible exa-scale computer architectures
    - interconnect which can support 10000+ nodes
    - energy efficiency technologies
    - prototype development
      - 512 nodes
      - 5-10TFlops/node
      - 10-20Gflops/W
      - point to point bandwidth>200Gbps
      - MPI latency<1.5us
    - system software for prototypes
    - 3 typical applications to verify effectiveness

1. Development of E-scale computer

- Key technology
  - Multi-objective optimized architecture
    - exa-scale architecture under the constraints of performance, energy consumption, programmability, reliability, and cost
  - Design of energy efficient computing node
    - 50-100TFlops/node
    - 30^{+}GFlops/w
  - Scheme for high performance processor/accelerator design
    - 20TFlops/chip
    - 40^{+}GFlops/W
    - Support multiple programming models

1. Development of E-scale computer

- Key technology
  - exa-scale system software
    - node OS
    - runtime
    - programming and software development environment
    - system management
    - parallel debugger and performance analysis tool
    - pursue good execution efficiency, program productivity, good manageability, and reliability
  - Highly scalable high speed interconnect
    - high bandwidth, low latency
    - support interconnection of tens-of-million cores
  - Scalable parallel I/O architecture and fault-tolerant storage system
    - scalable storage architecture
    - fault-tolerance techniques
    - large capacity, high bandwidth, high availability and balanced scalability

1. Development of E-scale computer

- Key technology
  - exa-scale system engineering
    - high density assembly
    - high efficient power supply
    - high efficient cooling
  - energy saving techniques
    - multi-layer effort
    - hardware and software coordination
  - exa-scale system reliability and fault-tolerance
  - exa-scale system modeling and performance measurement

1. Development of E-scale computer

- exa-scale computer system development
  - exaflops in peak
  - Linpack efficiency >60%
  - 10PB memory
  - EB storage
  - 30GF/w energy efficiancy
  - interconnect >500Gbps
  - large scale system management and resource scheduling
  - Easy-to-use parallel programming and software development
  - system monitoring and fault tolerance
  - support to large scale applications

1. Development of E-scale computer

- Technology transfer
  - High-end domain-oriented servers based on exa-scale system technologies
    - developing high performance servers for domain applications based on exa-scale computer technologies
      - high performance computing node
      - interconnect
      - scalable I/O
      - storage
      - energy saving
      - reliability
      - application software

2. HPC application development

- Basic research on exa-scale modeling methods, parallel algorithms, and parallel performance optimization
- Developing HPC application systems
- Establishing applications R&D centers to establish the HPC application eco-system

2. HPC application development

- Basic research
  - computable modeling and novel computational methods suitable for exa-scale systems
  - application-oriented exa-scale parallel performance optimization: theories and methods
  - scalable high-efficient parallel algorithms and parallel libraries for exa-scale computing

2. HPC application development

- Key technology and demo application
  - high performance numerical devices and their applications
    - numerical nuclear reactor
      - four components: Including reactor core particle transport, thermal hydraulics, structural mechanics and material optimization,
      - non-linear coupling of multi-physics processes
    - numerical aircraft
      - multi-disciplinary optimization covering aerodynamics and structural strength analysis
    - numerical earth
      - earth system modeling for studying climate change
      - non-linear coupling of multi-physical and chemical processes covering atmosphere, ocean, land, and sea ice
    - numerical engine
      - high fidelity simulation system for numerical prototyping of commercial aircraft engine
      - enabling fast and accurate virtual airworthiness experiments

2. HPC application development

- Key technology and demo application
  - high performance application software for key industry and their applications
    - application software for simulation of complex electromagnetic environment, optimized design of large fluid machinery, numerical simulation and optimized design of cars, design of complex engineering project and critical equipment, energy exploration, numerical simulation of ocean, internet application, large scale hydrological simulation
    - achieving exa-scale numerical simulations
  - high performance application software for research and demo applications
    - application software for scientific research in material science, biology and medicine, and scientific discovery
    - verification by demo-applications

2. HPC application development

- Key technology and demo application
  - application software products and demo-applications
    - develop application software in fluid dynamics computation, structural strength computation, material computation, biological computation
    - deploy the software on the high performance computers in the national HPC environment
    - obtain numerical simulation achievements as good as the ones by commercial software
    - each one is adopted by at least 50 users
    - pave the foundation of the HPC software industry

2. HPC application development

- Key technology and demo application
  - programming framework for exa-scale HPC application software development
    - structured mesh programming
    - unstructured mesh programming
    - mesh-free combinatory geometry programming
    - finite element programming
    - graph computing programming
    - support development of at least 40 million-core software
  - pre- and post-processing and user interface software

2. HPC application development

- Research, development and dissemination mechanism
  - establish 3 national-level research and development centers for HPC application software
  - form the national HPC eco-system together with the national supercomputing centers and the institutes developing the high performance computers
  - show the value of high performance computing in promoting competitiveness in innovation

3. HPC environment development

- **Major tasks**
  - Developing system-level software and operation platform for the national high performance computing environment
  - Developing a national HPC environment with leading class computing resources and service capability
  - Developing service systems based on the national HPC environment

3. HPC environment development

- Basic research
  - models and architecture for computing service
    - resource representation, usage and management, and service models
    - support to transformation of the national HPC environment
  - virtual data space
    - models, architecture, access and management of the virtual data space
    - develop virtual data space system and deploy it in the national HPC environment

3. HPC environment development

- Key technology
  - service mechanisms and supporting technical systems for the national HPC environment
    - new mechanisms and enabling technologies required by service–mode operation
    - upgrading of the national HPC environment (CNGrid)
      - Infrastructure nature
      - service mode operation
      - new operation mechanisms
      - >500PF computing resources, >500PB storage, >500 application software and tools
      - >5000 users (team user)
    - support to research, social and economical development of China

3. HPC environment development

- Key technology
  - application development and optimization techniques in the wide area heterogeneous environment
    - techniques and tools for application development, deployment, and optimization in the national HPC environment
    - improve productivity and quality of application systems

3. HPC environment development

- Demo applications
  - service systems deployed in the national HPC environment
    - integrated business platform, e.g.
      - complex product design optimization
      - HPC-enabled EDA platform
      - remote sensing data processing platform
    - domain problem-solving environment, e.g.
      - monitoring and fast response to disaster
      - processing and visualization of massive multi-source earth science data
      - space environment and its influence to space vehicles
    - application villages, e.g.
      - innovation and optimization of industrial products
      - drug discovery
      - computational chemistry/bioinformation
      - digital media
    - platform for education
      - provide computing resources and services to undergraduate and graduate students

First call

- The first call of the key project was issued on Feb. 19, 2016
- It covers selected topics from the three areas
  - prototypes of the next generation computers
  - HPC applications
  - parallel program framework
  - supporting platform for HPC environment
  - service systems based on the HPC environment
- The proposals will be reviewed in the next two months

Thank you!