HPC AT C-DAC: CAPABILITY AND CAPACITY BUILDING

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Presentation Outline

- National Initiative for Supercomputing Program
- C-DAC Activities, Evolution and Roadmap
- Indigenous Products, Technologies and Solutions
- Scientific & Engineering Research Areas
- Creation of HPC skilled manpower
- HPC Solutions and Services Offered
- C-DAC’s Success Stories in HPC
- Challenges Ahead
Almost all developed nations have their supercomputing policies

Scientific Advisory Committee to the Prime Minister of India has recommended the initiation of a national supercomputing program

The recommendation recently received an in-principle approval from the Planning Commission of India

Efforts will diverge on multiple verticals to cater to the nation’s vital R&D needs, as well as seek to develop technology that can be commercialized to meet revenue demands
C-DAC ACTIVITIES

Science & Engineering, Strategic Sectors, Health, e-Governance, Education, Power & Industrial Sector, Agriculture, Rural Areas, ...

End-to-End Solutions

Enabling Technologies

MISSION

360º HPC Solutions & Services

To place C-DAC as a One Stop Solution Provider for HPC and GRID Computing
C-DAC HPC: EVOLUTION AND ROAD MAP

1991

PARAM 8000
Technology Denial

1994

PARAM 9000

1998

PoC
100 Mbps
17 Locations

Garuda – Grid Computing
Social Computing with participatory approach

2002-03

PARAM Yuva
2008 54 TF

PARAM Padma
Viable HPC business computing environment

2014

1 PF

Garuda Grid Computing

PARAM 10000
Platform for User community to interact/ collaborate
High Performance Computing at C-DAC

**Hardware**
- High-Performance System Design
- VLSI Design
- System Area Networks (SAN)

**System Software & Utilities**
- Communication Protocols & Message Passing Interface libraries
- Compilers, debugging tools & Integrated development environments
- Parallel File Systems
- System Monitoring and Management Tools

**Application Software**
- Scientific & Engineering
- Business & Commercial
About PARAMNet-3

- Indigenous, high performance cluster interconnect
  - CDAC’s fourth generation network

- Consists of tightly integrated hardware and software components
  - Network Interface Card: Based on GEMINI co-processor
  - Packet Routing Switch
  - LWP software stack “KSHIPRA”
PARAMNet-3 Components: NIC

- Based on GEMINI: 4th Generation Communication Co-Processor Developed by C-DAC
- Protocol Offload Engine in Hardware, supporting Send/Recv, RDMA and datagram communication protocols
- Based on PCI-e (4X/8X) host interface and 10Gbps CX-4 physical link interface
- 16 MB onboard fast memory
- User level access to 4096 hardware endpoints
- Virtual address support with protection
Packet Routing Switch

- Modular Chassis based Architecture
- 48 Ports with each port working at 10Gbps full duplex
- Aggregate switching throughput of approx 1 Terabits/sec
- Low latency (1 us), near wire speed throughput for each port
- Support for large clusters through multi-staging
Kshipra

- Program Development Environment (PdE) for PARAMNet-3
- Supports two RDMA enabled Industry Standard Interfaces
  - Direct Access Provider Library (DAPL)
  - Open Fabrics Enterprise Distribution (OFED) stack
- Enables a whole gamut of networking applications from HPC / Enterprise computing areas
RECONFIGURABLE COMPUTING
SYSTEM CARD

- C-DAC has pioneered the RC technology for HPC in India through its state-of-the-art design of re-configurable hardware, system software and hardware libraries ('Avatars').

- Avatars are dynamically changeable circuits, corresponding to the compute intensive routines of the application code.

- C-DAC with its expertise in RC is capable of providing accelerated solutions for a wide spectrum of scientific and engineering areas.

- Bioinformatics sequence search solution using RC, gave 240 times faster results.

- C-DAC's own fracture mechanics code, having double precision Cholesky factorization and forward-backward substitution steps ported on RC provided 16X speedup.

- High speed data acquisition and signal processing solutions designed for Very Long Baseline Interferometry (VLBI) and power spectrum experimentation in radio astronomy, replaced a sizable computing cluster.
RECONFIGURABLE COMPUTING SYSTEM CARD

RC Product Features:

- Up to Twelve million gates, FPGAs for mapping compute intensive portions of application codes
- Standard bus interface like PCI/PCI-X/PCI Express
- System software Interface for all standard Linux distributions

RC in Supercomputing Cluster:
Param Yuva is the latest 54 TF supercomputer from C-DAC. 16 nodes of this machine are incorporated with RC hardware creating a powerful and unique supercomputing environment. Based on the configuration and application, RC enabled node delivers performance comparable to hundreds of CPU cores.
GARUDA

- GARUDA is India's first national grid initiative bringing together academic, scientific and research communities for developing their data and compute intensive applications with guaranteed QoS.

- GARUDA grid is an aggregation of resources comprising of computational nodes, mass storage and scientific instruments distributed across the country.
GARUDA

- National Grid Computing Initiative delivered through PoC and Foundation phase with infrastructure resources, tools, engineering, partner building and application enabled implementation

- Applications of National importance for community building
  - Disaster Management, Computer Aided Engineering (CAE), Collaborative Learning, Molecular Modeling, GMRT data processing and analysis, Cancer BioMedical Informatics Grid

- Building the Grid community Applications

- Interoperability between Garuda and European Grid infrastructure (EGEE)

- Indian Grid Certification Authority (IGCA)

- Progressive Overlaying over National Knowledge Network
CHREME
C-DAC’S HPC RESOURCE MANAGEMENT ENGINE

- An indigenously developed web based HPC Portal
- Intuitive and feature-rich Portal to provide GUI to extensive functionalities and configuration of the scientific models. This front-end will basically modularize the models execution process by providing the workflow structure for different execution stages.
- Allows users to configure their execution environment through compilers and libraries selection, scheduling parameters etc.
- Submission (uses cluster job scheduler at the backend), monitoring and management of jobs through GUI. Timely E-mail notification regarding job status; personalized job list and job status information.
- Secure credential specific access on web through https
- GUI for utilization and management of HPC resources
ONAMA

Little exposure to HPC in Academia !!!

- Few Engineering Institutes use HPC ...
- Limited Proliferation of High Performance Computing
  - Perception: Prohibitively high cost
  - Non Availability of total solution from one vendor
  - No Appropriate Training and Hand-Holding

C-DAC Offerings

- Engineering Application Software Solution (Onama)
- Parallel Programming Environment
- Total HPC Hardware Solution
- Training / Workshops
Onama is an integrated package which opens a new door to future technocrats, providing them a Quantum leap in developing a firm understanding through HPC in several engineering disciplines.

Onama comprises of a well selected set of parallel & serial applications and tools across various engineering disciplines such as Computer Science, Mechanical, Electronics and Communication, Electrical, Civil, Chemical engineering etc. Besides, it consists of a number of nVIDIA CUDA enabled applications in several domains such as molecular dynamics and physics.
Scientific & Engineering Applications

Computational Fluid Dynamics
- Hypersonic flow Simulation
- 3D Navier Stokes’ Solutions
- Heat Transfer in a Calandria

Computational Structural Mechanics
- Stress Analysis of Fibre Reinforced Composite Structures
- Fracture Mechanics
- Nonlinear Stability Analysis

Seismic Data Processing
- Prestack and Poststack Migration
- Elastic & Acoustic wave modeling
- Innovative Algorithm development
- Data Management & Validation
- Waveform Inversion
Scientific & Engineering Applications

**Evolutionary Computing**
- Protein Structure Prediction
- Multiple Sequence Alignment
- Material Modeling
- Genetic Algorithms

**Bioinformatics**
- Molecular Modelling
- Genome Sequence Analysis
- Comparative Genomics
- Problem Solving Environment

**Computational Atmospheric Science**
- Mesoscale Modeling (MM5)
- Climate System Model (CCSM)
- Medium Range Weather Forecasting
- Air Pollution Control

**Computational Chemistry**
- Molecular Properties
- \textit{ab initio} Electronics Structure
- Atomic and Molecular Electronic Structure Calculations

www.cdacindia.com
OPTIMIZATION, PARALLELIZATION AND CUSTOMIZATION OF APPLICATIONS

- Optimization of Codes
- Parallelization of Serial Applications with widely used parallel programming models such as MPI and OpenMP
- Implementation of Scientific & Engineering Applications onto massively Parallel GPGPU Platform
- Customization of codes to incorporate users requirement
Applications Ported

- Weather Research and Forecasting (WRF) Model
- Mesoscale model (MM5)
- T172
- T80
- Regional Climate Model (RegCM3)
- Regional Ocean Modeling System (ROMS)
- WRF-Var model
- ECHAM5
- CFS (Climate Forecast System)
- RegCM3 (Regional Climate Model)
- CCSM (Coupled Climate Model System)
- Precis (Providing Regional Climates for Impacts Studies)
- MOZART (Model of Ozone and Related Tracers)
- ECHAM5 Model

- Modular Ocean Model (MOM4)
- Cosmos (Community Earth System Models)
- Nemo (Nucleus for European Modelling of the Ocean)
- ROMS (Regional Ocean Modeling System)

- Phoenics
- OpenFOAM
Applications Ported

- T-Coffee
- Biopython
- Circular Genome Viewer (CGVIEW)
- ClustalW
- FASTA
- Glimmer
- PHYLogeny Inference Package (PHYLIP)
- mpiBLAST
- GROMACS
- EMBOSS
- HMMER
- MrBayes
- GMAP

- Ray2mesh
- Seisan
- OpenSEES
- LsqrSolve
- Gimbos
- Sismo-VTK

- Gaussian
- Nwchem
- AMBER
- Gamess
- MPQC
- Gromacs
- Lamps
- NAMD
- Quantum ESPRESSO
- ABINIT
C-DAC Certified HPC Professional Program (CCHPCP)

- Addresses the dire need of Skilled HPC Manpower
- CCHPCP shall assist the Government, R&D and IT industry to recruit the right candidates from a pool of HPC industry ready and certified professionals.
- Valuable, industry-Recognized credential that shall signify a proven level of knowledge and skills in HPC
- A first-of-its-kind in HPC
- Set an industry benchmark
- Individuals must know what skills make them qualified for HPC jobs
- The certification program will grade the examinee’s knowledge and understanding of C, C++, FORTRAN, Uniprocessor Optimization of Serial codes, Parallel Computing architectures & challenges, OS Concepts, Cluster building & System Administration, MPI, OpenMP, Profiling & Debugging of Codes, pthreads, GPGPU technology, Grid Computing, Cloud Computing and Accelerators.
Career Scope

- Addresses the dire need of Skilled HPC Manpower
- Greater competitive edge to students because of highly specialized area i.e. HPC & this increases the probability of working for world’s top research & commercial organizations.

- Trends Show Huge Growth in Parallel Programming Job Market.
  - Since November 2009:
    - CUDA jobs increased by 22%
    - OpenMP jobs increased by 85%
    - MPI jobs increased by 33%

Reference:
www.simplyhired.com
HPC Solutions and Services Offered

Technology Based Solutions
Consultancy Services
Software Integration Services
Facility Management Services
Deployment of Indigenous Technologies
Training & Workshops
TECHNOLOGY BASED SOLUTIONS

Computing Facilities and Labs
Data Visualization
Computer Aided Design and Animation
Communication & Data Network
Data Center Design
Data Storage
Scientific & Enterprise Application
CONSULTANCY SERVICES

HPC Facilities
Data Centers & Computing facilities
IT Infrastructure Security Audit
Disaster Recovery & Business Continuity Planning
Capacity planning of IT, Communication and Storage
Capacity Planning for Power and Cooling resources
Communication and Data Networks
SOFTWARE INTEGRATION SERVICES

Heterogeneous Computing & Communication Environments

Data Storage & Data Backup Solutions

Communication & Data Network Security Solutions
Facility Management services are aimed to support specific functions as per the clients’ requirements.

Resident Engineer support  
System Administration  
Application Porting  
Facility Maintenance Services  
IT, Communication & Utility Resource Management
TRAINING & WORKSHOPS

- Parallel & Multicore Programming
- System Administration & Management
- Storage Management Technologies
- Facility Operations Management and Maintenance
- GPGPU based Programming
- HPC User Symposiaums
- Network Security & Audits
C-DAC’s Success Stories in HPC
Russian Indian Centre For Advanced Computing Research (RICCR)

Accreditation for RICCR
Ministry of Industry, Science & Technology,
Russian Federation

Fundamentals of turbulence

Impact Analysis
Study of Monsoon Dynamics using PARAM

Simulation (September 12, 2003)

Numerical (Ocean - Atmosphere)

Numerical (Atmosphere)
PARAM System Layout at NCMRWF
Physical Research Laboratory, Ahmedabad
HPC Solution

- Master Node
- Compute Node 1
- Compute Node 20
- I/O Server
- Back-up Server
- Management Node
- FC Storage
- Tape Library
- Visualization node

Network Connections:
- 24 port IB Switch
- 48 port Ethernet Switch (IPMI)
- 48 port Ethernet Switch
- FC
- IB
- IPMI
- Gigabit

Management Console
Indian Institute of Tropical Meteorology, Pune  HPC Solution

Node 1 [x4600]

Node 2 [x4600]

Node 3 [x4600]

Node 4 [x4600]

Node 5 [x4600]

Node 6 [x4600]

Node 7 [x4600]

Node 8 [x4600]

Gigabit Ethernet Switch

24 TB SATA Storage [x4500]

16 Port Brocade Switch

4 TB SAS Storage [ST 2540]

24 Port IB 4 x DDR Switch

Visualization/Management Node [w24]

Tape Drive [SL 24]
4 TF Facility at North East Hill University (2009)
OTHER HPC CLIENTS OF C-DAC

- CTSF, Government of India, India
- NCL, Pune India
- IISER, Pune
- IMD, Pune
- IISc, Bangalore
- NEIST, Jorhat
- NIRD, Hyderabad
- NESAC, Meghalaya
- TIFR, India
- IUCAA, Pune, India
- Bharathidasan University, Trichy, India
- NML, Jamshedpur, India
- CCSHAU, HISAR, India
- PARAM provided to all IITs in India
FOREIGN COLLABORATIONS

- Russian Indian Centre For Advanced Computing Research (RICCR)
- Center for Excellence in ICT, Govt. of Vietnam
- Center for Excellence in ICT, Govt. of Tanzania
- Center for Excellence in ICT, Govt. of Armenia
- Center for Excellence in ICT, Govt. of Belarus
- Center for Excellence in ICT, Govt. of Myanmar
- Center for Excellence in ICT, Govt. of Ghana
Challenges Ahead

- Heterogeneous Computing (Multi-cores, Many-cores, FPGA based Accelerators…)
- Application Scalability
- Algorithms Development
- Application check pointing/ restart /migration
- Green Computing
- Virtualization
- Interconnection Network (Topology, Bandwidth, Latency, Protocols)
- Reliable components, Preventive Maintenance and Monitoring
- Power and Cooling
- ….
Applying Advanced Computing for Human Advancement

Thank you

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