# Tsinghua University Team in SC18 Student Cluster Competition

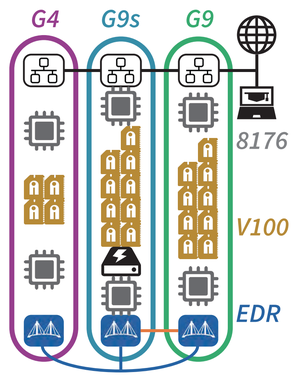

Jiping Yu, Liyan Zheng, Jia'ao He, Xinjian Yu, Chenggang Zhao, Chenyao Lou and Jidong Zhai

*Department of Computer Science and Technology, Tsinghua University, Beijing 100084, China*


*we will win powered by a*

## well-designed architecture

### networking and cluster overview




*3 nodes: G4, G9s, G9*
- 168 CPU cores, 2 sockets per node
- 22 GPU accelerators, 4+9+9 distributed

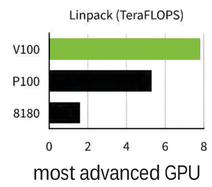
*Infiniband EDR*
- 100 Gbps bandwidth with 0.7 s latency
- 2 subnets, better concurrent task control

*10 Gigabit Ethernet chain:*
- stable for management and monitoring
- lower power consumption than a switch

### cutting-edge computing hardware

Thanks NVIDIA for kindly o ering *Tesla® V100*!

*equipped on all 3 nodes*
*V100 x (4+9+9)*
benchmarked apps optimized implemented to be GPU memory friendly



most advanced GPU

900 GB/s memory bandwidth

250 Watts power consumption

26 GFLOPS/Watts exceptional e iciency

*Intel® Xeon Platinum Processors* are deployed with AVX-512

*equipped*
*8176 x (2+2+2)*

Best performance with 165W TDP

:-) 2.2x acceleration from E5-2699v4
:-) hexa channel to achieve 126 GB/s
:-) 28 cores with AVX-512

Other hardware configuration:
- *DDR4 2666 MT/s 16 GB x (12+12+12)*: reasonable capacity
  - 6 per socket to work in hexa channel for full bandwidth
- *Intel® SSD DC S3610 100 GB on G4 & G9*
  *Intel® SSD DC S4600 960 GB on G9s*
  - high-performace OS and libraries
- *Intel® SSD DC P3608 4 TB on G9s*: blazing fast shared storage
  - up to 5 GB/s sequential read and 3 GB/s sequential write
- *Hot plug, Redundant Power Supply 1000 W x (2+4+4)*: load balance

### so ware choices

- *Debian GNU/Linux 9 'stretch'*: stable and reproducible
  - always up to date without expensive subscription
  - friendly to HPC applications with native support
  - keep up with lastest Linux kernel 4.9.110
- *Modified Telegraf*: control and monitoring on cluster resources
- *Spack*: flexible package manager for HPC
  - manage multiple versions of compilers, utilities and libraries
  - Intel® Compilers 17/18/19; GCC 6.3/8.2
  - Intel® MPI 2017/18/19; Mellanox® HPC-X; OpenMIP 1.10.7/3.1.2
  - NVIDIA® CUDA 8/9/10; CuDNN 5/6/7
- *ZFS on Linux*: robust, e icient file system
  - periodical snapshots, fast recovery from misoperation
  - pool-based storage, easy for managing and sharing

*we will win for*

## specialized optimization

### general methodology

*Profiling*: find out the hotspots of each application
- Allinea MAP, Intel® VTune Amplifier, NVIDIA® Profiling Tools
- allow us to pay attention to time consuming parts

*Code improving*:
- vectorization with SIMD intrinsics, o loading to accelerators
- overlapping communication and computation
- cache optimization, data alignment, branch prediction

*Compile*: with recent optimizing compilers and tune options
*Tuning*: mpitune, CPU a inity, NUMA binding, etc

### LINPACK & HPCG

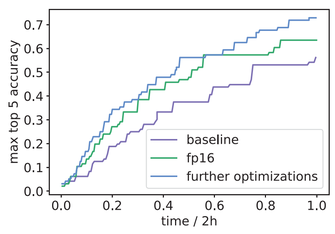
*Tune program input parameters*:
- fully understand and tune settings including sizes and algorithms
- script-driven automatic optimizing

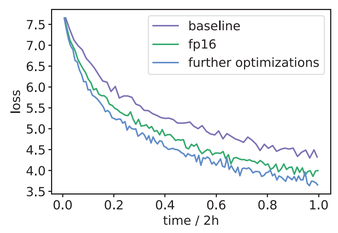
*Optimize communication and balance threads to GPUs ratio*

### reproducibility (SeisSol)

*Port to CORE-AVX-512*: reproduce on a brand new architecture
*Allinea MAP*: trace hardware counters and analyze performance
*Hyperthreading*: study on its impact on performance

### Horovod



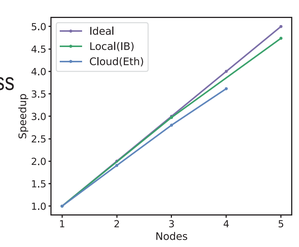

*Data compressor*: compress data before synchronizing the gradients
- compress data from `float64/32` to `float16`
- strike a balance between speed and precision

*Relax Synchronization*: add pacman_relax_allreduce method
- directly return the results of last round
- tune `batch_size` and `learning_rate` for this method

### OpenMC

*Hotspot analysis*: find out what makes it slow and try to improve
- locate the bottleneck: memory access
- eliminate atomic operations and random memory access

*Compiler mystery*: ICC built version runs more than 10 times slower than GCC



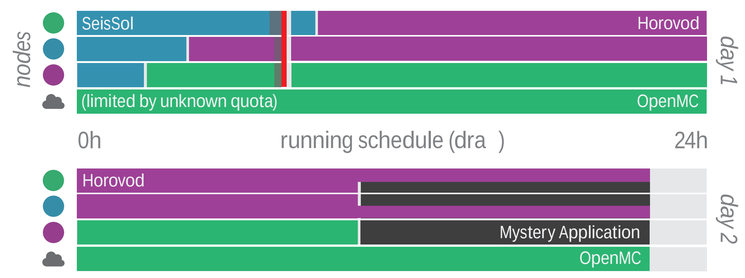

### mystery application

*Di erent compiling methods*: thanks to *Spack*
*Resource preservation*: preserve *G4* and an IB subnet for it
*Analysis*: communication-intensity and GPU-friendliness

*we will win since we have*

## sophisticated tactics

### scheduling in the allotted time



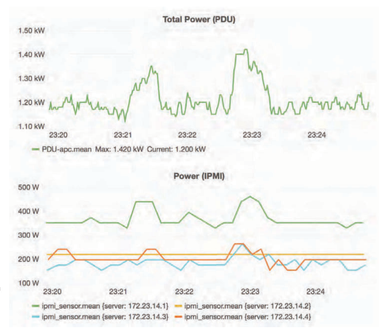

- *Reproducibility (SeisSol)*:
  - high priority for performance evaluation to start report writing
  - finish scalability tests first to gradually release nodes
- *Horovod*:
  - allocate most local cluster time of *G9s*, *G9*
  - occupy most local resources, leave the rest for mystery application
- *OpenMC*:
  - allocate most of the cloud cluster quota and most local time of *G4*
- *Mystery Application*:
  - run last a er deep analysis and optimization
  - decide to use the cloud or local cluster based on analysis
  - choose run time based on optimization and scoring rubric
- *Power Shut-o* :
  - implement checkpointing in all applications
  - lose tolerable amount of work

### controlling over power consumption

*Monitoring*

realtime with *Grafana*
cluster metrics from SNMP
server data from IPMI
fine-grained CPU & GPU
metrics collecting with agent

- quicker decision making
- knowing what is consuming
- balanced e iciency
- more metrics like bandwidth, throughput, IOwait, etc.




*Controlling*
- *P-state*: adjust with *tuned* using *tuned*-adm
- *C-state*: controlled by P-state, put CPU more o en into C6
- *Turbo Boost*: disable boost with */sys* settings
- *Enhanced SpeedStep*: reduce CPU frequency with *cpupower*
- *GPU Power*: balance energy with *nvidia-smi*
- *Daemon*: disable useless daemon to reduce overhead

more secrets…… ;-)

(members monitoring & controlling the power in ISC 18)

*we will win with a team of*

## diversity and collaboration

### create a diverse team

*Diversity of genders*:
- members of di erent genders
- male and female candidates in preparing stage

*Diversity of birthplaces (particularly in China)*:
- members from 13 di erent provinces
- each with di erent cultural backgrounds

Di erent Place of Birth

*Diversity of experience*:
- di erent years of study
- experienced HPC contestants and newbies
- one backup member still in *high school*

*Diversity of personal interests*:
- took di erent courses: architecture, algorithm, OS, AI, database, etc.
- interest in di erent fields: math modeling, neural networks, blockchain, etc.
- have di erent social works: student union, Linux user group, etc.
- di erent extracurricular activities: ballroom dancing, triathlon, cycling, etc.
- plan on di erent future: doctoral/master study, work, startup, etc.

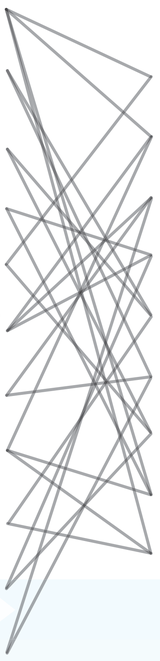
*Diversity of majors*:
- computer science, economics, math, interdisplinary science, physics

*Actively encourage females, sophomores and students with interdisiplinary knowledge to join us*

### collaboration based on di erent majors and skill sets

- *Jiping Yu*: Computer Science
  - operating system, database
- *Yu Chen*: Computer Science
  - compiling, algorithm, CUDA
- *Liyan Zheng*: Economics & CS
  - algorithm, so ware engineering
- *Shizhi Tang*: Computer Science
  - artificial neural networks
- *Jia'ao He*: Computer Science
  - web development, physics
- *Chenyao Lou*: Interdisplinary Science
  - network, algorithm, systems
- *Chenggang Zhao*: Computer Science
  - MPI, architecture, research
- *Shengqi Chen*: Math & CS
  - devops, network, LaTeX
- *Chen Zhang*: Computer Science
  - discrete optimization, design
- *Yuxian Gu*: Computer Science
  - mathematical modeling
- *Xinjian Yu*: Computer Science
  - distributed systems, blockchain

*...More backup members...*

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- Spirit: Actions Speak Louder than Words

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*Corresponding author: zhaijidong@tsinghua.edu.cn*