AI Bridging Cloud Infrastructure (ABCI) and its I/O Architecture

Algorithm + Big Data + Computing Power + Infrastructure

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ABCI: The World’s First Large-Scale Open AI Infrastructure

- World Top-Level compute and data process capability
- Open, Public, and Dedicated infrastructure for AI & Big Data Algorithms, Software, and Applications
- Open Innovation Platform to accelerate joint academic-industry R&D for AI

Peak Performance:
- 550 PFLOPS (FP16)
- 37 PFLOPS (FP64)

Effective Performance: (as of June 2019)
- 19.88 PFLOPS (#8 in TOP500)
- 14.423 GFLOPS/W (#4 in GREEN500)
- 508.85 TFLOPS (#5 in HPCG)

Power Usage: < 2.3 MW
Average PUE: < 1.1 (Estimated)
AI Infrastructure for Everyone

Expert
- ABCI Grand Challenge: Demonstration of highly challenging academic and/or industrial themes using the whole ABCI resources for 24 hours for free

Advanced & Intermediate
- Up to 512-node computing resource is available for everyone
- Software, datasets, and pre-trained models are ready for use
- High computing capability enables to accelerate AI R&D and promote social implementation

Beginner
- User friendly WebUI based IDE for supporting beginners of deep learning
- PoC platform for B2B2C business model

Promoting the use by over 100 institutions and over 1000 researchers/engineers
World’s Highest Speed in ImageNet-1k Training

ImageNet / ResNet-50 (Relative speedup & Accuracy)
Large-scale Reinforcement Learning for Computer Go

Large-scale Video Analysis Demonstration in cooperation between ABCI and SINET5

- **Video/Action label**
- **AI/SUM in Tokyo**
- **Live demonstration of huge volume video data analysis by ABCI**

**ABCI**
AI Bridging Cloud Infrastructure
https://abci.ai/ja/

**SINET5**
https://www.sinet.ad.jp/

**3D ResNet [1]**
State-of-the-art 3D CNN-based action recognition developed by AIST

- 3D filter
- Convolution map (3D)

High-speed R&E network operated by NII (100Gbps)

- Live video from WebCam

SONY began providing User friendly WebUI based Deep Learning Toolkit w/ using ABCI (Apr 8\textsuperscript{th} just announced)

https://dl.sony.com/ja/cloud/abci/index.html
AI Datacenter & Facility
AI Datacenter
“Commoditizing supercomputer cooling technologies to Cloud (70kW/rack)”

- Single floor, cost effective building
- Hard concrete floor 2t/m² weight tolerance for racks and cooling pods
- Number of Racks
  - Initial: 90 (ABCI uses 41 racks)
  - Max: 144
- Power capacity: 3.25 MW
  - ABCI uses 2.3MW max
- Cooling capacity: 3.2MW
  - 70kW/rack: 60kW water + 10kW air
Hybrid Water/Air Cooling System

Outdoor Facilities

Cooling Tower

Fan Coil Unit (FCU)

Water 32°C

Air 35°C

2nd closed circuit

Water 40°C

Air 40°C

1st closed circuit

CDU

Cooling Pod / Rack

Computing Node

Water

40°C

Water

32°C

Water Cooling

Water Block

Air

40°C

Air

35°C
ABCI HW/SW Overview
**High-Performance Computing System**

- **550 PFlops (FP16)**, **37.2 PFlops (FP64)**
- **476 TiB Memory**, **1.74 PB NVMe SSD**

**Computing Nodes (w/ GPU) x 1088**

- GPU: NVIDIA Tesla V100 SXM2 x 4
- CPU: Intel Xeon Gold 6148 (2.4GHz/20cores) x 2
- Memory: 384GiB
- Local Storage: Intel SSD DC P4600 (NVMe) 1.6TB x 1
- Interconnect: InfiniBand EDR x 2

**Multi-platform Nodes (w/o GPU) x 10**

- Intel Xeon Gold 6132 (2.6GHz/14cores) x 2
- 768GiB Memory, 3.8TB NVMe SSD

**Interactive Nodes x 4**

**Management and Gateway Nodes x 15**

**Gateway and Firewall**

- Nexus 3232C x2
- FortiGate 1500D x2
- FortiAnalyzer 400E x1

**Large-scale Storage System**

- **22 PB GPFS + 1 PB Lustre + 17 PB Scality RING Object Storage**

**DDN SFA14K (w/ SS8462 Enclosure x 10) x 3**

- 12TB 7.2Krpm NL-SAS HDD x 2400
- 3.84TB SAS SSD x 216
- NSD Server x 12

**DDN SFA14KX (w/ SS9012 Enclosure x 5) x 1**

- 7.68TB SAS SSD x 185, 900GB x 13
- MDS Server x 2, OSS Server x 4

**HPE Apollo 4510 Gen10 x 24**

- 12TB SATA HDD x 1440
- 3.2TB SSD x 24

**Interconnect (InfiniBand EDR)**

- Mellanox CS7500 x 2
- Mellanox SB7890 x 229

**Service Network (10GbE)**

**100Gbps SINET5**
ABCI Computing Node

FUJITSU PRIMERGY Server (2 servers in 2U)

<table>
<thead>
<tr>
<th>Component</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPU</td>
<td>Xeon Gold 6148 (27.5M Cache, 2.40 GHz, 20 Core) x2</td>
</tr>
<tr>
<td>GPU</td>
<td>NVIDIA Tesla V100 (SXM2) x4</td>
</tr>
<tr>
<td>Memory</td>
<td>384GiB DDR4 2666MHz RDIMM</td>
</tr>
<tr>
<td>Local Storage</td>
<td>1.6TB NVMe SSD (Intel SSD DC P4600 u.2) x1</td>
</tr>
<tr>
<td>Interconnect</td>
<td>InfiniBand EDR x2</td>
</tr>
</tbody>
</table>

**CPU blade**

**GPU blade**
ABC High-Performance Computing System

Chips (GPU, CPU)

- Tesla V100
- Xeon Skylake-SP

Compute Node (4GPUs, 2CPUs)

- PRIMERGY CX2570 M4

Node Chassis (2 Compute Nodes)

- PRIMERGY CX400 M4

Rack (17 Chassis)

- 1088 Compute Nodes
- 4352 GPUs

System (32 Racks)

- Full Bisection BW within Rack
- 70kW Max
- 1/3 of Oversubscription BW
- 2.3MW

GPU:
- 7.8 TFlops(FP64)
- 125 TFlops(FP16)

CPU:
- 1.53 TFlops(FP64)
- 3.07 TFlops(FP32)

- 34.2 TFlops(FP64)
- 506 TFlops(FP16)

- 68.5 PFlops(FP64)
- 1.01 PFlops(FP16)

- 1.16 PFlops(FP64)
- 17.2 PFlops(FP16)

- 37.2 PFlops(FP64)
- 0.55 EFlops(FP16)

- ~3.72 TB/s MEM BW
- 384 GiB MEM
- 200 Gbps NW BW
- 1.6TB NVMe SSD

- ~131TB/s MEM BW
- Full Bisection BW within Rack
- 70kW Max
- 1/3 of Oversubscription BW
- 2.3MW

NVIDIA Tesla V100
(16GB SMX2)
ABCi Computing Rack / Interconnect

- **Dense-packaged rack: 34 nodes, 136 Tesla V100**
  - Theoretical peak performance per rack: 1.16 PFlops (FP64), 17 PFlops (FP16)
  - c.f. Google TPU 3.0 Pod (>100PFlops/8racks)
  - Power consumption per rack: 67.33 kW

- **Interconnect**
  - Fat-tree topology
  - Intra-rack: full bisection BW
  - Inter-rack: 1/3 over-subscription (2400/6800)
  - Large-scale storage system: full bi-section BW
### Hierarchical Storage Layer of ABCI

<table>
<thead>
<tr>
<th>Tier</th>
<th>Storage Systems</th>
<th>Comments</th>
</tr>
</thead>
</table>
| **Scratch**                               | **Local SSD 1.6 TB**                                  | 😁 Fast as possible  
                                | **BeeOND based Parallel FS**                         | 😂 Limited capacity |
| **Hot Data, Container Imgs**              | **Lustre based Parallel FS 1PB**                      | 😁 Fast meta ops, IOPS  
                                |                                                      | 😂 Limited to 200GB per user |
| **Big/Cold/Archive Data**                 | **GPFS based Parallel FS 22PB**                       | 😁 Capacity, aggregated throughput  
                                |                                                      | 😂 Eventually slow, esp. small files, meta ops |
| **Import/Export**                         | **Scality RING based Object Storage 17PB**            | 😁 S3-conformant data access  
                                |                                                      | 😂 Fine-grained access control  
                                |                                                      | 😁 Data/transfer encryption  
                                |                                                      | 😂 Expandable  
                                |                                                      | 😂 Slow, hard to configure |
## ABCI Software Stack

### Software

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating System</td>
<td>CentOS / RHEL 7.6</td>
</tr>
<tr>
<td>Job Scheduler</td>
<td>Univa Grid Engine 8.6.3</td>
</tr>
<tr>
<td>Container Engine</td>
<td>Docker 17.12.0</td>
</tr>
<tr>
<td></td>
<td>Singularity 2.6.1</td>
</tr>
<tr>
<td>MPI</td>
<td>Intel MPI 2018.2.199</td>
</tr>
<tr>
<td></td>
<td>MVAPICIH2 2.3rc2, 2.3 / MVAPICH2-GDR 2.3a, 2.3rc1, 2.3, 2.3.1</td>
</tr>
<tr>
<td></td>
<td>OpenMPI 1.10.7, 2.1.3, 2.1.5, 2.1.6, 3.0.3, 3.1.0, 3.1.2, 3.1.3</td>
</tr>
<tr>
<td></td>
<td>PGI Professional Edition 17.10, 18.5, 18.10, 19.3</td>
</tr>
<tr>
<td></td>
<td>NVIDIA CUDA SDK 8.0, 9.0, 9.1, 9.2, 10.0</td>
</tr>
<tr>
<td></td>
<td>cuDNN 5.1, 6.0, 7.0, 7.1, 7.2, 7.3, 7.4, 7.5</td>
</tr>
<tr>
<td></td>
<td>NCCL 1.3.5, 2.1, 2.2, 2.3, 2.4</td>
</tr>
<tr>
<td></td>
<td>GCC, Python, Ruby, R, OpenJDK, Go, Perl</td>
</tr>
<tr>
<td>Deep Learning</td>
<td>Caffe, Caffe2, TensorFlow, Theano, Torch, PyTorch, CNTK, MXnet, Chainer, Keras, etc.</td>
</tr>
<tr>
<td></td>
<td><em>(Frameworks provided by NVIDIA GPU Cloud can also be deployed)</em></td>
</tr>
<tr>
<td>Big Data Processing</td>
<td>Hadoop, Spark</td>
</tr>
</tbody>
</table>
ABCI Software Stack

Container support

- Containers enable users to instantly try the state-of-the-art software developed in AI community
- ABCI supports two container technologies
  - Docker, having a large user community
  - Singularity, recently accepted HPC community
- ABCI provides various single-node/distributed deep learning framework container images optimized to achieve high performance on ABCI
  - NGC (NVIDIA GPU Cloud) plays the key role for realizing this
BeOND on ABCI
BeeOND on ABCI

- Build a temporal BeeGFS (v7.1.2) partition for each job
  - Users have to conduct explicit data staging between global filesystems and BeeOND filesystem
- The feature is enabled by a directive of job script

```bash
#!/bin/sh
#$-l rt_F=2
#$-l USE_BEEOND=1
#$-l h_rt=1:00:00
#$-cwd
```

Job contents

- Only Full node instance is supported
- Specify USE_BEEOND => mounted on /beeond

---

**BeeGFS Default Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>#MDS</td>
<td>1</td>
</tr>
<tr>
<td>#SS</td>
<td>#Hosts</td>
</tr>
<tr>
<td>Filesystem Size</td>
<td>#Hosts * 1.6TB</td>
</tr>
<tr>
<td>Stripe Size *</td>
<td>512KB</td>
</tr>
<tr>
<td>Stripe Count *</td>
<td>4</td>
</tr>
</tbody>
</table>

* : Parameters can be changed by users
BeeOND Performance on ABCI

- Use IOR and MDTEST to measure weak scaling performance
  - 2 nodes to 32 nodes (within a rack)
- Sequential Read/Write
  - Use 40 process/node, 16 GiB/process, File/proc => 640 GiB/node
  - Transfer size is 4KB
- Random Read/Write
  - Same as Sequential Read/Write
  - 300 seconds IO
- IO Patterns
  - Each process access to different files (FPP: File Per Process)

<table>
<thead>
<tr>
<th>Single SSD IOR Performance</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sequential Read</td>
<td>2959 MB/s</td>
</tr>
<tr>
<td>Sequential Write</td>
<td>1452 MB/s</td>
</tr>
<tr>
<td>Random Read</td>
<td>1519 MB/s</td>
</tr>
<tr>
<td>Random Write</td>
<td>302 MB/s</td>
</tr>
</tbody>
</table>
BeeOND Performance on ABCI
Sequential Read/Write

- Good weak scalability but some performance degradation against Ideal
- BeeOND outperforms GPFS when more than 32 nodes (within a rack) are used
BeeOND Performance on ABCI Random Read/Write

- Scalability of BeeOND is good although there are large gap between Ideal scalability
  - Performances of read and write against Ideal are 30% and 40%, respectively
- Performance of GPFS was very bad because of mismatch of transfer size (4K) and GPFS block size (4M)