Update from Intel®: Insights into Intel® innovations for HPC and AI

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Intel Corporation

9th MultiCore Workshop. September 26th, 2019
National Center for Atmospheric Research, Boulder, CO
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Tests document performance of components on a particular test, in specific systems. Differences in hardware, software, or configuration will affect actual performance. Consult other sources of information to evaluate performance as you consider your purchase. For more complete information about performance and benchmark results, visit www.intel.com/benchmarks.

Intel technologies’ features and benefits depend on system configuration and may require enabled hardware, software or service activation. Performance varies depending on system configuration.

Intel® Advanced Vector Extensions (Intel® AVX)* provides higher throughput to certain processor operations. Due to varying processor power characteristics, utilizing AVX instructions may cause a) some parts to operate at less than the rated frequency and b) some parts with Intel® Turbo Boost Technology 2.0 to not achieve any or maximum turbo frequencies. Performance varies depending on hardware, software, and system configuration and you can learn more at http://www.intel.com/go/turbo.

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Agenda

- Introduction: Moore's Law, is it really ending?
- Overview of the latest generation of Intel® Xeon® Processor and roadmap
- Overview of coming technologies: oneAPI, DAOS, CXL, ...
- Performance study of Intel® Xeon® Scalable Processor using mainstream HPC and ESM workloads
- Examples of HPC-AI convergence use cases from our customers
Acknowledgments

- Chris Allison, Nitya Hariharan, Nalini Kumar, Victor Lee, Andrea Luiselli, Johann Lombardi, Vikram Saletore, Stephen Van Doren
Moore’s Law: 1965

“With unit cost falling as the number of components per circuit rises, by 1975 economics may dictate squeezing as many as 65000 components on a single silicon chip”
Is Moore’s Law ending?

“Everything that can be invented has been invented”
Charles H. Duell
US Patent Commissioner 1899

“Moore’s Law won’t work at feature sizes less than a quarter of a micron”
Erich Bloch
Head of IBM Research, later Chairman of NSF 1988

“There is nothing new to be discovered in physics now”
Lord Kelvin 1900

The End of Moore's Law?
The current economic boom is likely due to increases in computing speed and decreases in price. Now there are some good reasons to think that the party may be ending.
by Charles C. Mann
May 1, 2000

“Moore Sees ‘Moore’s Law’ Dead in a Decade”
By Mark Hachman on September 18, 2007 at 5:12 pm | 1 Comment 2007
In a “fireside chat” with NPR “Tech Nation’s” Moira Gunn, Intel co-founder and chairman emeritus Gordon Moore said he sees his famous law expiring in 10 to 15 years.

Moore's Law limit hit by 2014?
The high cost of semiconductor manufacturing equipment is making continued chipmaking advancements too expensive, threatening Moore’s Law, according to iSuppli. 2009

Death of Moore's Law Will Cause Economic Crisis
By John E. Dunn
Techworld.com | May 21, 2011 11:00 AM PST

Moore's Law Is Dead. Now What?
Shrinking transistors have powered 50 years of advances in computing—but now other ways must be found to make computers more capable. 2016

Life After Moore's Law
By Bill Dally 2010

“The End of History”
Francis Fukuyama 1989

Intel’s View

Jim Keller, SVP, General Manager, Silicon Engineering Group, Intel
UC Berkeley EECS Colloquium, September 18th, 2019.

Short summary: Moore’s Law will keep proceeding. There is a path to get 50x gate density.

Link to a talk: https://eecs.berkeley.edu/research/colloquium/190918
The 2nd generation of Intel® Xeon® Scalable Processor and Overview of Next-Generation Data Center Products
INCREASING THE PACE OF INNOVATION

2014

INTEL® XEON®
PROCESSOR E5 V3
HASWELL

2015

INTEL® XEON®
PROCESSOR E5 V4
BROADWELL

2016

INTEL® XEON®
SCALABLE PROCESSOR
SKYLAKE

2017

2ND GEN INTEL® XEON®
SCALABLE PROCESSOR
CASCADE LAKE

2018

COOPER LAKE
&
ICE LAKE

2019

 SAPPHIRE
RAPIDS

2020

2021

2022

NEXT GEN

DRIVING LEADERSHIP WORKLOAD PERFORMANCE

5 TO 7 QUARTER CADENCE

MOVING TO

4 TO 5 QUARTER CADENCE
AVAILABLE TODAY

2ND GENERATION INTEL® XEON® SCALABLE PROCESSOR

2X
AVERAGE PERFORMANCE IMPROVEMENT1
COMPARSED TO INTEL® XEON® PLATINUM 8180 PROCESSOR

UP TO 30X
AI PERFORMANCE WITH INTEL® DL BOOST2
COMPARSED TO INTEL® XEON® PLATINUM 8180 PROCESSORS (JULY 2017)

UP TO 5.8X
BETTER PERFORMANCE THAN AMD EPYC* 76013
COMPARSED TO INTEL® XEON® PLATINUM 9282 PROCESSOR RUNNING LINPACK

HIGHEST DDR4
NATIVE BANDWIDTH OF ANY INTEL® XEON® PLATFORM

HIGHEST FLOPS
PER 2S SYSTEM WITH INTEL® ARCHITECTURE

HIGHEST DENSITY
INTEL® XEON® SCALABLE PROCESSOR CORES IN A 2S SYSTEM

Performance results are based on testing as of dates shown in configuration and may not reflect all publicly available security updates, see details on slide 44. For more complete information about performance and benchmark results, visit www.intel.com/benchmarks.
# INTEL® XEON®: ONWARDS AND UPWARDS

## The ONLY Datacenter CPU Optimized for Convergence

- INTEL® ADVANCED VECTOR EXTENSIONS 512
- INTEL® DEEP LEARNING BOOST (INTEL® DL BOOST)
- INTEL® OPTANE™ DC PERSISTENT MEMORY

<table>
<thead>
<tr>
<th>2019</th>
<th>2020</th>
<th>2021</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CASCADE LAKE</strong></td>
<td><strong>COOPER LAKE</strong></td>
<td><strong>SAPPHIRE RAPIDS</strong></td>
</tr>
<tr>
<td>14NM</td>
<td>14NM</td>
<td>NEXT GENERATION TECHNOLOGIES</td>
</tr>
<tr>
<td>NEW AI ACCELERATION (VNNI)</td>
<td>NEXT GEN INTEL DL BOOST (BFLOAT16)</td>
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</tr>
<tr>
<td>NEW MEMORY STORAGE HIERARCHY</td>
<td></td>
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<td></td>
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<td></td>
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<tr>
<td><strong>ICE LAKE</strong></td>
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<tr>
<td>10NM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SHIPPING 1H’20, SAMPLES SHIPPING NOW</td>
<td></td>
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</tr>
</tbody>
</table>
ACCELERATING CONVERGENCE
LEADERSHIP PERFORMANCE FOR DATA LEVEL PARALLEL HPC & AI WORKLOADS

7NM PROCESS TECHNOLOGY

EMIB (2D) AND FOVEROS (3D) TECHNOLOGY

POWERING AURORA
DELIVERED IN 2021
ACCELERATING INNOVATIONS FOR CONVERGENCE

MULTI OS
BETTER ISOLATION USING LIGHT WEIGHT KERNELS

UNIFIED CONTROL SYSTEM
SCALABLE, COHERENT COMPREHENSIVE SYSTEM VIEW

GEOPM
APPLICATION AWARE HOLISTIC POWER MANAGEMENT

PMIX
PROCESS MANAGEMENT WITH “INSTANT ON”

INTEL® XEON® SCALABLE PROCESSOR + MULTIPLE XE® ARCHITECTURE BASED GP-GPU IN EACH NODE

>10 PETABYTES MEMORY

>230 PETABYTES STORAGE (DAOS), BW >25TB/S

INTEL ONE API
FOCUSED INVESTMENTS TO ACCELERATE HPC & AI

ADVANCED ARCHITECTURES
- SCALAR
- VECTOR
- MATRIX
- SPATIAL
+ Quantum & Neuromorphic

Simplified programming

Manufacturing excellence
- PROCESS
  10th Gen Intel® Core™ Processor
- FPGA
- PACKAGING
  EMIB + “FOVEROS”
- Advanced packaging
  for heterogeneous integration

Intelligent interconnect
- Advanced high performant fabrics
- Interconnect beyond “I/O”

Simplified programming
- ONEAPI
  Services and Tools
- Unified single software abstraction
  and domain-specific libraries

Transforming memory & storage
- RE-ARCHITECTING THE MEMORY HIERARCHY AND FILE SYSTEMS

Built-in security
- Security at all levels: core, SOC, board, platform, & software
- Uniquely positioned to implement security technologies at every level

GROWING THE ECOSYSTEM AND ADVANCING HPC & AI THROUGH OPEN STANDARDS
ACCELERATING GLOBAL WEATHER FORECASTING … WITH FEWER I/O NODES

REDUCING OPENFOAM RUNTIME BY 50%

ACCELERATING MATERIAL SCIENCE RESEARCH ACROSS MULTIPLE DOMAINS

Performance results based on testing by EPCC. See slide 45 for system configuration details as provided by EPCC. The NEXTGenIO project is funded by the European Union’s Horizon 2020 Research and Innovation program under Grant Agreement no. 671951
Generational performance study of Intel® Xeon® Processor using HPC and ESM workloads
NWP and ESM HPC centers in Top500

From TOP500 List - June 2018

<table>
<thead>
<tr>
<th>Rank</th>
<th>Site</th>
<th>System</th>
<th>Cores</th>
<th>Rmax</th>
<th>Rpeak</th>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>United Kingdom Meteorological Office</td>
<td>Cray XC40, Xeon E5-2695v4 18C 2.10GHz, Aries interconnect Cray Inc.</td>
<td>241,920</td>
<td>7,038.9</td>
<td>8,128.5</td>
<td>kW</td>
</tr>
<tr>
<td>25</td>
<td>Japan Meteorological Agency</td>
<td>Cray XC50, Xeon Platinum 8160 2.10GHz, Aries interconnect Cray Inc./Hitachi</td>
<td>135,792</td>
<td>5,730.5</td>
<td>9,125.2</td>
<td>1,354</td>
</tr>
<tr>
<td>26</td>
<td>Japan Meteorological Agency</td>
<td>Cray XC50, Xeon Platinum 8160 2.10GHz, Aries interconnect Cray Inc./Hitachi</td>
<td>135,792</td>
<td>5,730.5</td>
<td>9,125.2</td>
<td>1,354</td>
</tr>
<tr>
<td>31</td>
<td>National Center for Atmospheric Research</td>
<td>Cheyenne - SGI ICE XA, Xeon E5-2697v4 18C 2.39GHz, Infiniband EDR HPSC</td>
<td>144,900</td>
<td>4,788.2</td>
<td>5,332.3</td>
<td>1,727</td>
</tr>
<tr>
<td>36</td>
<td>ECMWF</td>
<td>Cray XC40, Xeon E5-2695v4 18C 2.10GHz, Aries interconnect Cray Inc.</td>
<td>126,468</td>
<td>3,944.7</td>
<td>4,249.3</td>
<td>1,697</td>
</tr>
<tr>
<td>37</td>
<td>ECMWF</td>
<td>Cray XC40, Xeon E5-2695v4 18C 2.10GHz, Aries interconnect Cray Inc.</td>
<td>126,468</td>
<td>3,944.7</td>
<td>4,249.3</td>
<td>1,697</td>
</tr>
</tbody>
</table>

www.top500.org

Data represents an architecture view of supercomputing centers from Top500 which are 100% dedicated to weather/climate.
NWP and ESM HPC centers in Top500

Distribution by OEM

- Cray: 47%
- HPE: 24%
- Sugon: 9%
- Bull: 6%
- Dell: 4%
- IBM: 2%
- Fujitsu: 2%
- Huawei: 2%
- Inspur: 2%

➢ **Cray** covers almost a half of NWP/ESM HPC in Top500

Distribution by arch

- Intel Skylake: 16%
- Intel Broadwell: 39%
- Intel Haswell: 27%
- Ivy Bridge: 2%
- Intel Sandy Bridge: 11%
- AMD Opteron: 4%
- Fujitsu Sparc64: 1%

➢ **95% of NWP/ESM HPC runs on Intel architecture**

Data source: [www.top500.org](http://www.top500.org)
## Selected suite of NWP/ESM workloads

<table>
<thead>
<tr>
<th>Application</th>
<th>Version</th>
<th>Dataset</th>
<th>Compiler/MPI</th>
<th>Run</th>
</tr>
</thead>
<tbody>
<tr>
<td>WRF</td>
<td>3.9.1.1</td>
<td>CONUS-12km, CONUS-2.5km</td>
<td>Intel 2018 update 3</td>
<td>Out-of-the-box</td>
</tr>
<tr>
<td>MPAS-A</td>
<td>6.1</td>
<td>120km_L56, dycore+physics</td>
<td>Intel 2018 update 3</td>
<td>Out-of-the-box</td>
</tr>
<tr>
<td>NEMO</td>
<td>4.0</td>
<td>ORCA2_ICe_PISCES</td>
<td>Intel 2018 update 3</td>
<td>Out-of-the-box</td>
</tr>
<tr>
<td>HOMME</td>
<td>dungeon28</td>
<td>WACCM, NE=8</td>
<td>Intel 2018 update 3</td>
<td>Out-of-the-box</td>
</tr>
</tbody>
</table>
SUMMARY: Single Node Performance

Performance results are based on testing as of January 30, 2019 to April 30, 2019 and may not reflect all publicly available security updates. See configuration disclosure for details. No product can be absolutely secure. Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. Intel does not control or audit the design or implementation of third party benchmark data or Web sites referenced in this document. Intel encourages all of its customers to visit the referenced Web sites or others where similar performance benchmark data are reported and confirm whether the referenced benchmark data are accurate and reflect performance of systems available for purchase. Refer to Configuration: HPC Workloads – WRF CONUS-12km, WRF CONUS-2.5km, MPAS-A, NEMO, HOMME, STREAM Triad, HPL. *Other names and brands may be claimed as the property of others.
HPC-AI Convergence: Examples of HPC-AI Use Cases from Our Customers
HPC-AI Use Cases with Collaborations

AI INTEGRATED IN HPC WORKFLOWS
WEATHER PATTERN DETECTION

AI ACCELERATING HPC SIMULATIONS
DRUG DISCOVERY

AI REPLACING HPC SIMULATIONS
HIGH ENERGY PHYSICS
**DisCo - Unsupervised Detection of Spatiotemporal Structures**

First distributed-memory implementation of local causal state reconstruction:
- Outperforms state-of-art methods for complex fluid flows
- Unprecedented data processing capability (89.5TB lightcone data in 6.6 minutes on 1024 nodes)

Distributed implementations of K-Means and DBSCAN for high-dimensional data:
- Using standard scikit-learn like Python APIs in Intel® DAAL and daal4py

Achieved high performance while maintaining developer productivity:
- **30x** 1-node speedup, **91%** weak and **64%** strong scaling efficiency up to 1024 Intel® Haswell nodes

Joint collaboration of Intel, LBNL/NERSC, UC Davis

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https://www.groundai.com/project/towards-unsupervised-segmentation-of-extreme-weather-events/1
**HPC ↔ AI: IMAGE ANALYSIS FOR DRUG DISCOVERY**

**NOVARTIS**

**Joint Intel & Novartis collaboration**

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**Customer:**
Novartis Inst. of Biomedical Research (Switzerland) is one of the largest pharmaceutical companies in the world

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**Challenge:** High content screening of cellular phenotypes is a fundamental tool supporting early stage drug discovery. While analyzing whole microscopic images are desirable, these images are 26X larger than benchmark dataset such as ImageNet*-1K. As a result, the high computational workload with high memory requirement would be prohibitive for deep learning model training.

---

**Solution:** Intel and Novartis teams were able to scale and train the model with 32 TensorFlow* workers in 31 minutes.

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**RESULTS**

Processing 1024x1280 large image dataset, reducing the training time to 31 minutes to >99% accuracy on 2S Intel® Xeon® processor based cluster.

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High Content Screening Training with 313K Images on 64-Node Intel® 2S Xeon® Scalable processor 6148, TensorFlow*, “horovod*”, OpenMPI*, Batch Size=32/Node, Intel® Omni-Path™ Fabric
HPC ↔ AI: DIS/REPLACING MONTE CARLO SIM.
CERN HIGH ENERGY PHYSICS
JOINT COLLABORATION WITH INTEL AND SURF SARA

Customer: CERN, the European Organization for Nuclear Research, which operates the Large Hadron Collider (LHC), the world’s largest and most powerful particle accelerator.

Challenge: CERN currently uses Monte Carlo simulations for complex physics and geometry modeling, which is a heavy computational load that consumes up to >50% of the Worldwide LHC Computing Grid power for electron shower simulations.

Solution: Distributed training using 128 nodes of the TACC Stampede 2 cluster (Intel® Xeon® Platinum 8160 processor, Intel® OPA) and a 3D Generative Adversarial Network (3D GAN). Performance was first optimized on a single node then scaled using TensorFlow* optimized with Intel® MKL-DNN, using 4 workers/node and an optimized number of convolutional filters.

RESULT
94% scaling efficiency up to 128 nodes, with a significant reduction in training time per epoch for 3D-GANs & >2500X Inference

Time to create an electron shower

<table>
<thead>
<tr>
<th>Method</th>
<th>Machine</th>
<th>Time/Shower (msec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Simulation (geant4)</td>
<td>2S Intel® Xeon® Platinum 8180</td>
<td>17000</td>
</tr>
<tr>
<td>3D GAN (batch size 128)</td>
<td>2S Intel® Xeon® Platinum 8180</td>
<td>7</td>
</tr>
</tbody>
</table>

Inference Perf: >2500X


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Multi-Node Training Performance & Accuracy (2018)

Distributed training using data parallelism
94% Scaling efficiency up to 128 nodes
### Inference time

#### 2018

**Baseline (TF 1.9)**

<table>
<thead>
<tr>
<th>Method</th>
<th>Platform</th>
<th>Time/Shower (msecs)</th>
<th>Speedup</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classical Monte Carlo</td>
<td>2S Intel Xeon®</td>
<td>17000</td>
<td>1.0</td>
</tr>
<tr>
<td>(Geant4)</td>
<td>Platinum 8180</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3D GAN (BS=128) 1-Stream</td>
<td>2S Intel Xeon®</td>
<td>7</td>
<td>2500</td>
</tr>
<tr>
<td></td>
<td>Platinum 8180</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*measured on 10000 showers

#### 2019

**Further optimization (TF 1.13, MKL-DNN, 3D-Conv)**

<table>
<thead>
<tr>
<th>Method</th>
<th>Platform</th>
<th>Time/Shower (msecs)</th>
<th>Speedup</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classical Monte Carlo</td>
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<td>(Geant4)</td>
<td>Platinum 8180</td>
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<tr>
<td>3D GAN (BS=128) 1-Stream</td>
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<td>2500</td>
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<tr>
<td></td>
<td>Platinum 8180</td>
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<tr>
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<td>3D GAN (BS=128) 4-Stream</td>
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<td></td>
<td>Platinum 8180</td>
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</tbody>
</table>

Performance results are based on testing as of April, 2019 and may not reflect all publicly available security update. See configuration disclosure for details. No product can be absolutely secure.
oneAPI: Single Programming Model to Deliver Cross-Architecture Performance
INTEL DATA-CENTRIC HARDWARE: HIGH PERFORMANCE, FLEXIBLE OPTIONS

General Purpose
CPU

GPU
Intel®
Processor Graphics & Future Products

FPGA
Intel®
Stratix 10

Domain Optimized
Accelerator
Intel
Neural Network
Processor

GENERAL PURPOSE
Provide optimal performance
over the widest variety
of workloads

HARDWARE

WORKLOAD OPTIMIZED
Deliver highest performance
per $/Watt/U/Rack
for critical applications

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REVOLUTIONIZING PROGRAMMABILITY
INTEL’S ONE API

DATA PARALLEL C++

Based on C++ and uses C / C++ constructs
Incorporates SYCL* for data parallelism & heterogeneous programming
Language extensions driven through an open community project
First available – Q4 2019

* from the Khronos Group

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DIVERSE WORKLOADS REQUIRE DIVERSE ARCHITECTURES

The future is a diverse mix of scalar, vector, matrix, and spatial architectures deployed in CPU, GPU, AI, FPGA and other accelerators.
PROGRAMMING CHALLENGE

Diverse set of data-centric hardware

No common programming language or APIs

Inconsistent tool support across platforms

Each platform requires unique software investment
Project oneAPI delivers a unified programming model to simplify development across diverse architectures.

Common developer experience across Scalar, Vector, Matrix and Spatial architectures (CPU, GPU, AI and FPGA)

Uncompromised native high-level language performance

Based on industry standards and open specifications

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ONEAPI FOR CROSS-ARCHITECTURE PERFORMANCE

Optimized Applications

Optimized Middleware & Frameworks

oneAPI Product

Direct Programming

Data Parallel C++

API-Based Programming

Libraries

Analysis & Debug Tools

oneAPI Product

CPU

SCALAR

GPU

VECTOR

AI

MATRIX

FPGA

SPATIAL

Some capabilities may differ per architecture.

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Data Parallel C++
Standards-Based, Cross-Architecture Language

Language to deliver uncompromised parallel programming productivity and performance across CPUs and accelerators

Based on C++ with language enhancements being driven through community project

Open, cross-industry alternative to single architecture proprietary language

There will still be a need to tune for each architecture.

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ADVANCED ANALYSIS & DEBUG TOOLS

Productive performance analysis across SVMS architectures

**Intel® VTune™ Profiler**
Profiler to analyze CPU and accelerator performance of compute, threading, memory, storage, and more

**Intel® Advisor**
Design assistant to provide advice on threading, and vectorization

**Debugger**
Application debugger for fast code debug on CPUs and accelerators
SUMMARY

Diverse workloads for data-centric computing are driving the need for diverse compute architectures including CPUs, GPUs, FPGAs, and AI accelerators.

OneAPI unifies and simplifies programming of Intel CPUs and accelerators, delivering developer productivity and full native language performance.

OneAPI is based on industry standards and open specifications to encourage ecosystem collaboration and innovation.
More disclosures are coming in Q4

Thank you
DAOS: Distributed Asynchronous Object Storage

DAOS is the scale-out software-defined storage platform for HPC, Big Data, and AI convergence.

- High throughput/IOPS @ arbitrary alignment/size
- Low-latency I/O
- Data access time orders of magnitude faster (μs vs ms)
- Primary storage on Aurora exascale supercomputer at Argonne National Labs, with a capacity of 230PB and bandwidth >25TB/s.
To learn more about DAOS

ISC demonstration

- Live DAOS demo at the Intel Booth
  - IOR + Spark workloads
    - https://youtu.be/5RJbHwtHos0

- DAOS solution brief

Source code on GitHub:
- https://github.com/daos-stack/daos

DAOS public roadmap:
- https://wiki.hpdd.intel.com/display/DC/Roadmap

Admin Guide:
- http://daos.io/doc

Community mailing list on Groups.io:
- daos@daos.groups.io

Support:
- https://jira.hpdd.intel.com
Footnotes and configuration details

Performance results are based on testing as of dates shown in configuration and may not reflect all publicly available security updates. See configuration disclosure for details. No product or component can be absolutely secure. Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more complete information visit www.intel.com/benchmarks.

1 - 2x Average Performance Improvement compared with Intel® Xeon® Platinum 8180 processor. Geomean of est SPECrate2017_int-base, est SPECrate2017_fp_base, Stream Triad, Intel Distribution of Linpack, server side Java. Platform 92xx vs Platinum 8180: 1-node, 2x Intel® Xeon® Platinum 9282 cpu on Walker Pass with 768 GB (24x 32GB 2933) total memory, ucode 0x400000A on RHETL7.6, 3.10.0-957.el7.x86_65, IC19u1, AVX512, HT on all (off Stream, Linpack), Turbo on all (off Stream, Linpack), result: est int throughput=635, est fp throughput=526, Stream Triad=407, Linpack=6411, server side java=-332913, test by Intel on 2/16/2019. vs. 1-node, 2x Intel® Xeon® Platinum 8180 cpu on Wolf Pass with 384 GB (12 X 32GB 2666) total memory, ucode 0x200004D on RHEL7.6, 3.10.0-957.el7.x86_65, IC19u1, AVX512, HT on all (off Stream, Linpack), result: est int throughput=307, est fp throughput=251, Stream Triad=204, Linpack=3238, server side java=165724, test by Intel on 1/29/2019.

2 - Up to 30X AI performance with Intel® DL Boost compared to Intel® Xeon® Platinum 8180 processor (July 2017). Tested by Intel as of 2/26/2019. Platform: Dragon rock 2 socket Intel® Xeon® Platinum 9282 (56 cores per socket), HT ON, turbo ON, Total Memory 768 GB (24 slots/ 32 GB/ 2933 MHz), BIOS: SE5620 86B.00.01.0241.1120021802249, Centos 7 Kernel 3.10.0-957.5, el7.x86_64, Deep Learning Framework: Intel® Optimization for Caffe version: https://github.com/intel/caffe d554cbf1, ICC 2019.2.187, MKL DNN version: v0.17 (commit hash: 830a10059a018cd2634d94195140cf2d8790a75a), model: https://github.com/intel/caffe/blob/master/models/intel_optimized_models/int8/resnet50_int8_full_conv.prototxt, BS=64, No datalayer DummyData:3x224x224, 56 instance/2 socket, Datatype: INT8 vs Tested by Intel as of July 11th 2017: 2S Intel® Xeon® Platinum 8180 CPU @ 2.50GHz (28 cores), HT disabled, turbo disabled, scaling governor set to “performance” via Intel® pstate driver, 384GB DDR4-2666 ECC RAM. CentOS Linux release 7.3.1611 (Core), Linux kernel 3.10.0-514.10.2.el7.x86_64, SSD: Intel® SSD DC S3700 Series (800GB, 2.5in SATA 6Gb/s, 25nm, MLC). Performance measured with: Environment variables: KMP_AFFINITY='granularity=socket' and scaling governor set to "performance" via cpupower frequency-set -d 2.5G -u 3.8G -g performance. Caffe: (http://github.com/intel/caffe/), revision f96b759f71b2281835f690af267158b82b150b5c. Inference measured with “caffe time --forward_only” command, training measured with “ConvNet output” dummy batch size, set with numactl -I. For “ConvNet output” dummy batch size, set with numactl -I.

3 – Up to 5.8X better performance than AMD EPYC 7601 compared to Intel® Xeon® Platinum 9282 processor running LINKPACK. AMD EPYC 7601: Supermicro AS-2023US-TR4 with 2 AMD EPYC 7601 (2.2GHz, 32 core) processors, SMT OFF, Turbo ON, BIOS ver 1.1a, 4/26/2018, microcode: 0x8001227, 16x32GB DDR4-2666, 1 SSD, Ubuntu 18.04.1 LTS (4.17.0-041700-generic Retpoline), High Performance Linpack v2.2, compiled with Intel(R) Parallel Studio XE 2018 for Linux, Intel MPI version 18.0.0.128, AML BLIS ver 0.4.0, Benchmark Config: Nb=232, N=168960, P=4, Q=4, Score =1095GFs, tested by Intel as of July 31, 2018. vs. 1-node, 2x Intel® Xeon® Platinum 9282 cpu on Walker Pass with 768 GB (24x 32GB 2933) total memory, ucode 0x400000A on RHETL7.6, 3.10.0-957.el7.x86_65, IC19u1, AVX512, HT off, Turbo on, server side java=-8411, test by Intel on 2/16/2019. vs. 1-node, 2x Intel® Xeon® Platinum 8280M cpu on Wolf Pass with 384 GB (12 X 32GB 2933) total memory, ucode 0x400000A on RHETL7.6, 3.10.0-957.el7.x86_65, IC19u1, AVX512, HT off Linpack, Turbo on, score=-3462, test by Intel on 1/30/2019.
Footnotes and configuration details

System Configuration details as provided by EPCC for performance results on slide 15
34 DP nodes with Cascade Lake 8260M CPUs (A0 stepping), Fujitsu mainboard
96 GByte DDR4 DRAM per socket (6x16 GByte DIMMs, 2666 speed grade), plus 1.5 TByte Intel Optane DC Persistent Memory (6x256 GByte DIMMs, QS)
Dual-Rail Omni-Path networks (2 OPA NICS per node) connected via 2 48-port OPA switches
Two additional Storage server nodes running Lustre

Figure 16: NEXTGenIO Solution Stack
Footnotes and configuration details

WRF CONUS-12km (higher is better):

2S Intel® Xeon® E5-2697 v3 Processor: 1-node Intel reference platform, 2x Intel® Xeon® E5-2697 v3 processor (2.6GHz, 14C), 8x16GB DDR4-2133, HT on (1 thread/core), Turbo on, 1 SSD SATA, BIOS: SE5C610.86B.01.0026.121720182203, Microcode: 0x3e, Oracle Linux Server release 7.6 (compatible with RHEL 7.6) on a 7.5 kernel using ksplice for security fixes, Kernel: 3.10.0-957.5.1.el7.crt1.x86_64. WRF version 3.9.1.1, Workload: CONUS-12km, compiled with AVX512, Intel® Parallel Studio XE 2018 Update 3 and Intel MPI 2018 Update 3, Relative performance=1.00, tested by Intel on 04/29/2019.

2S Intel® Xeon® E5-2697 v4 Processor: 1-node Intel reference platform, 2x Intel® Xeon® E5-2697 v4 processor (2.3GHz, 18C), 8x16GB DDR4-2400, HT on (1 thread/core), Turbo on, 1 SSD SATA, BIOS: SE5C610.86B.01.0028.121720182203, Microcode: 0xb000030, Oracle Linux Server release 7.6 (compatible with RHEL 7.6) on a 7.5 kernel using ksplice for security fixes, Kernel: 3.10.0-957.5.1.el7.crt1.x86_64. Workload: CONUS-12km, compiled with AVX512, Intel® Parallel Studio XE 2018 Update 3 and Intel MPI 2018 Update 3, Relative performance=1.16, tested by Intel on 04/29/2019.

2S Intel® Xeon® Gold 6148 Processor: 1-node Intel reference platform, 2x Intel® Xeon® Gold 6148 processor (2.4GHz, 20 cores per socket), 12*16GB DDR4-2666, HT on (1 thread/core), Turbo on, 1 SSD SATA, BIOS: SE5C620.86B.00.01.0016.020120190930, Microcode ver 0x200001c, Oracle Linux Server release 7.6 (compatible with RHEL 7.6) on a 7.5 kernel using ksplice for security fixes, Kernel: 3.10.0-957.5.1.el7.crt1.x86_64. Workload: CONUS-12km, compiled with AVX512, Intel® Parallel Studio XE 2018 Update 3 and Intel MPI 2018 Update 3, Relative performance=1.68, tested by Intel on 04/29/2019.

2S Intel® Xeon® Platinum 8260 Processor: 1-node Intel reference platform, 2x Intel® Xeon® 8260 Intel processors (2.4GHz, 24C), 12x16GB DDR4-2933, HT on (1 thread/core), Turbo on, 1 SSD SATA, BIOS: SE5C620.86B.02.01.0008.031920191559, Microcode: 0x4000000c, Oracle Linux Server release 7.6 (compatible with RHEL 7.6) on a 7.5 kernel using ksplice for security fixes, Kernel: 3.10.0-957.5.1.el7.crt1.x86_64. Workload: CONUS-12km, compiled with AVX512, Intel® Parallel Studio XE 2018 Update 3 and Intel MPI 2018 Update 3, Relative performance=1.88, tested by Intel on 04/29/2019.

2S Intel® Xeon® Platinum 9242 Processor: 1-node Intel reference platform, 2x Intel® Xeon® 9242 processors (2.2GHz, 48C), 24x16GB DDR4-2933, HT on (1 thread/core), Turbo on, 1 SSD SATA, BIOS: SE5C620.86B.0D.01.0456.033120191654, Microcode: 0x40000021, Oracle Linux Server release 7.6 (compatible with RHEL 7.6) on a 7.5 kernel using ksplice for security fixes, Kernel: 3.10.0-957.5.1.el7.crt1.x86_64. Workload: CONUS-12km, compiled with AVX512, Intel® Parallel Studio XE 2018 Update 3 and Intel MPI 2018 Update 3, Relative performance=3.62, tested by Intel on 04/29/2019.
Footnotes and configuration details

WRF CONUS-2.5km (higher is better):

2S Intel® Xeon® E5-2697 v3 Processor: 1-node Intel reference platform, 2x Intel® Xeon® E5-2697 v3 processor (2.6GHz, 14C), 8x16GB DDR4-2133, HT on (1 thread/core), Turbo on, 1 SSD SATA, BIOS: SE5C610.86B.01.0028.121720182203, Microcode: 0x3e, Oracle Linux Server release 7.6 (compatible with RHEL 7.6) on a 7.5 kernel using ksplice for security fixes, Kernel: 3.10.0-957.5.1.el7.crt1.x86_64. WRF version 3.9.1.1, Workload: CONUS-2.5km, compiled with AVX512, Intel® Parallel Studio XE 2018 Update 3 and Intel MPI 2018 Update 3, Relative performance=1.00, tested by Intel on 04/30/2019.

2S Intel® Xeon® E5-2697 v4 Processor: 1-node Intel reference platform, 2x Intel® Xeon® E5-2697 v4 processor (2.3GHz, 18C), 8x16GB DDR4-2400, HT on (1 thread/core), Turbo on, 1 SSD SATA, BIOS: SE5C610.86B.01.0028.121720182203, Microcode: 0xb000030, Oracle Linux Server release 7.6 (compatible with RHEL 7.6) on a 7.5 kernel using ksplice for security fixes, Kernel: 3.10.0-957.5.1.el7.crt1.x86_64. Workload: CONUS-2.5km, compiled with AVX512, Intel® Parallel Studio XE 2018 Update 3 and Intel MPI 2018 Update 3, Relative performance=1.25, tested by Intel on 04/30/2019.

2S Intel® Xeon® Gold 6148 processor: 1-node Intel reference platform, 2x Intel® Xeon® Gold 6148 processor (2.4GHz, 20 cores per socket), 12x16GB DDR4-2666, HT on (1 thread/core), Turbo on, 1 SSD SATA, BIOS: SE5C620.86B.00.01.0016.02120190930, Microcode ver 0x2000050, Oracle Linux Server release 7.6 (compatible with RHEL 7.6) on a 7.5 kernel using ksplice for security fixes, Kernel: 3.10.0-957.5.1.el7.crt1.x86_64. Workload: CONUS-2.5km, compiled with AVX512, Intel® Parallel Studio XE 2018 Update 3 and Intel MPI 2018 Update 3, Relative performance=1.78, tested by Intel on 04/30/2019.

2S Intel® Xeon® Platinum 8260 Processor: 1-node Intel reference platform, 2x Intel® Xeon® Platinum 8260 Intel processors (2.4GHz, 24C), 12x16GB DDR4-2933, HT on (1 thread/core), Turbo on, 1 SSD SATA, BIOS: SE5C620.86B.02.01.0008.031920191559, Microcode: 0x400001c, Oracle Linux Server release 7.6 (compatible with RHEL 7.6) on a 7.5 kernel using ksplice for security fixes, Kernel: 3.10.0-957.5.1.el7.crt1.x86_64. Workload: CONUS-2.5km, compiled with AVX512, Intel® Parallel Studio XE 2018 Update 3 and Intel MPI 2018 Update 3, Relative performance=2.04, tested by Intel on 04/30/2019.

2S Intel® Xeon® Platinum 9242 Processor: 1-node Intel reference platform, 2x Intel® Xeon® Platinum 9242 processors (2.2GHz, 48C), 24x16GB DDR4-2933, HT on (1 thread/core), Turbo on, 1 SSD SATA, BIOS: SE5C620.86B.0D.01.0456.03120191654, Microcode: 0x4000021, Oracle Linux Server release 7.6 (compatible with RHEL 7.6) on a 7.5 kernel using ksplice for security fixes, Kernel: 3.10.0-957.5.1.el7.crt1.x86_64. Workload: CONUS-2.5km, compiled with AVX512, Intel® Parallel Studio XE 2018 Update 3 and Intel MPI 2018 Update 3, Relative performance=4.00, tested by Intel on 04/30/2019.
Footnotes and configuration details

MPAS-A (higher is better):

2S Intel® Xeon® E5-2697 v3 Processor: 1-node Intel reference platform, 2x Intel® Xeon® E5-2697 v3 processor (2.6GHz, 14C), 8x16GB DDR4-2133, HT on (1 thread/core), Turbo on, 1 SSD SATA, BIOS: SE5C610.86B.01.0028.121720182203, Microcode: 0x3e, Oracle Linux Server release 7.6 (compatible with RHEL 7.6) on a 7.5 kernel using ksplice for security fixes, Kernel: 3.10.0-957.5.1.el7.crt1.x86_64. MPAS-A version 6.1, Workload: 120km_L56, compiled with AVX512, Intel® Parallel Studio XE 2018 Update 3 and Intel MPI 2018 Update 3, Relative performance=1.00, tested by Intel on 04/26/2019.

2S Intel® Xeon® E5-2697 v4 Processor: 1-node Intel reference platform, 2x Intel® Xeon® E5-2697 v4 processor (2.3GHz, 18C), 8x16GB DDR4-2400, HT on (1 thread/core), Turbo on, 1 SSD SATA, BIOS: SE5C610.86B.01.0028.121720182203, Microcode: 0xb000030, Oracle Linux Server release 7.6 (compatible with RHEL 7.6) on a 7.5 kernel using ksplice for security fixes, Kernel: 3.10.0-957.5.1.el7.crt1.x86_64. MPAS-A version 6.1, Workload: 120km_L56, compiled with AVX512, Intel® Parallel Studio XE 2018 Update 3 and Intel MPI 2018 Update 3, Relative performance=1.24, tested by Intel on 04/26/2019.

2S Intel® Xeon® Gold 6148 processor: 1-node Intel reference platform, 2x Intel® Xeon® Gold 6148 processor (2.4GHz, 20 cores per socket), 12x16GB DDR4-2666, HT on (1 thread/core), Turbo on, 1 SSD SATA, BIOS: SE5C620.86B.00.01.0016.0210190930, Microcode ver 0x2000050, Oracle Linux Server release 7.6 (compatible with RHEL 7.6) on a 7.5 kernel using ksplice for security fixes, Kernel: 3.10.0-957.5.1.el7.crt1.x86_64. MPAS-A version 6.1, Workload: 120km_L56, compiled with AVX512, Intel® Parallel Studio XE 2018 Update 3 and Intel MPI 2018 Update 3, Relative performance=1.67, tested by Intel on 04/26/2019.

2S Intel® Xeon® Platinum 8260 Processor: 1-node Intel reference platform, 2x Intel® Xeon® Platinum 8260 Intel processors (2.4GHz, 24C), 12x16GB DDR4-2933, HT on (1 thread/core), Turbo on, 1 SSD SATA, BIOS: SE5C620.86B.02.00.0008.031920191559, Microcode: 0x4000021, Oracle Linux Server release 7.6 (compatible with RHEL 7.6) on a 7.5 kernel using ksplice for security fixes, Kernel: 3.10.0-957.5.1.el7.crt1.x86_64. MPAS-A version 6.1, Workload: 120km_L56, compiled with AVX512, Intel® Parallel Studio XE 2018 Update 3 and Intel MPI 2018 Update 3, Relative performance=1.95, tested by Intel on 04/26/2019.

2S Intel® Xeon® Platinum 9242 Processor: 1-node Intel reference platform, 2x Intel® Xeon® Platinum 9242 processors (2.2GHz, 48C), 24x16GB DDR4-2933, HT on (1 thread/core), Turbo on, 1 SSD SATA, BIOS: SE5C620.86B.0D.01.0456.033120191654, Microcode: 0x4000021, Oracle Linux Server release 7.6 (compatible with RHEL 7.6) on a 7.5 kernel using ksplice for security fixes, Kernel: 3.10.0-957.5.1.el7.crt1.x86_64. MPAS-A version 6.1, Workload: 120km_L56, compiled with AVX512, Intel® Parallel Studio XE 2018 Update 3 and Intel MPI 2018 Update 3, Relative performance=4.07, tested by Intel on 04/26/2019.
Footnotes and configuration details

NEMO (higher is better):

**2S Intel® Xeon® E5-2697 v3 Processor**: 1-node Intel reference platform, 2x Intel® Xeon® E5-2697 v3 processor (2.6GHz, 14C), 8x16GB DDR4-2133, HT on (1 thread/core), Turbo on, 1 SSD SATA, BIOS: SE5C610.86B.01.0028.121720182203, Microcode: 0x3e, Oracle Linux Server release 7.6 (compatible with RHEL 7.6) on a 7.5 kernel using ksplice for security fixes, Kernel: 3.10.0-957.5.1.el7.crt1.x86_64. NEMO version 4.0, Workload: ORCA2_ICE_PISCES, compiled with AVX512, Intel® Parallel Studio XE 2018 Update 3 and Intel MPI 2018 Update 3, Relative performance=1.00, tested by Intel on 04/25/2019.

**2S Intel® Xeon® E5-2697 v4 Processor**: 1-node Intel reference platform, 2x Intel® Xeon® E5-2697 v4 processor (2.3GHz, 18C), 8x16GB DDR4-2400, HT on (1 thread/core), Turbo on, 1 SSD SATA, BIOS: SE5C610.86B.01.0028.121720182203, Microcode: 0xb000030, Oracle Linux Server release 7.6 (compatible with RHEL 7.6) on a 7.5 kernel using ksplice for security fixes, Kernel: 3.10.0-957.5.1.el7.crt1.x86_64. NEMO version 4.0, Workload: ORCA2_ICE_PISCES, compiled with AVX512, Intel® Parallel Studio XE 2018 Update 3 and Intel MPI 2018 Update 3, Relative performance=1.23, tested by Intel on 04/25/2019.

**2S Intel® Xeon® Gold 6148 processor**: 1-node Intel reference platform, 2x Intel® Xeon® Gold 6148 processor (2.4GHz, 20 cores per socket), 12*16GB DDR4-2666, HT on (1 thread/core), Turbo on, 1 SSD SATA, BIOS: SE5C620.86B.00.01.0016.020120190930, Microcode ver 0x2000050, Oracle Linux Server release 7.6 (compatible with RHEL 7.6) on a 7.5 kernel using ksplice for security fixes, Kernel: 3.10.0-957.5.1.el7.crt1.x86_64. NEMO version 4.0, Workload: ORCA2_ICE_PISCES, compiled with AVX512, Intel® Parallel Studio XE 2018 Update 3 and Intel MPI 2018 Update 3, Relative performance=1.74, tested by Intel on 04/25/2019.

**2S Intel® Xeon® Platinum 8260 Processor**: 1-node Intel reference platform, 2x Intel® Xeon® 8260 Intel processors (2.4GHz, 24C), 12x16GB DDR4-2933, HT on (1 thread/core), Turbo on, 1 SSD SATA, BIOS: SE5C620.86B.02.01.0008.031920191559, Microcode: 0x400001c, Oracle Linux Server release 7.6 (compatible with RHEL 7.6) on a 7.5 kernel using ksplice for security fixes, Kernel: 3.10.0-957.5.1.el7.crt1.x86_64. NEMO version 4.0, Workload: ORCA2_ICE_PISCES, compiled with AVX512, Intel® Parallel Studio XE 2018 Update 3 and Intel MPI 2018 Update 3, Relative performance=2.15, tested by Intel on 04/25/2019.

**2S Intel® Xeon® Platinum 9242 Processor**: 1-node Intel reference platform, 2x Intel® Xeon® 9242 processors (2.2GHz, 48C), 24x16GB DDR4-2933, HT on (1 thread/core), Turbo on 1, SSD SATA, BIOS: SE5C620.86B.0D.01.0456.033120191654, Microcode: 0x4000021, Oracle Linux Server release 7.6 (compatible with RHEL 7.6) on a 7.5 kernel using ksplice for security fixes, Kernel: 3.10.0-957.5.1.el7.crt1.x86_64. NEMO version 4.0, Workload: ORCA2_ICE_PISCES, compiled with AVX512, Intel® Parallel Studio XE 2018 Update 3 and Intel MPI 2018 Update 3, Relative performance=4.43, tested by Intel on 04/25/2019.
Footnotes and configuration details

HOMME (higher is better):

**2S Intel® Xeon® E5-2697 v3 Processor**: 1-node Intel reference platform, 2x Intel® Xeon® E5-2697 v3 processor (2.6GHz, 14C), 8x16GB DDR4-2133, HT on (1 thread/core), Turbo on, 1 SSD SATA, BIOS: SE5C610.86B.01.0028.121720182203, Microcode: 0x3e, Oracle Linux Server release 7.6 (compatible with RHEL 7.6) on a 7.5 kernel using ksplice for security fixes, Kernel: 3.10.0-957.5.1.el7.crt1.x86_64. HOMME version dungeon28ps://github.com/homme-dycore, WACC benchmark, Intel Parallel Studio XE 2018 Update 3, Intel MPI 2018u3, Relative performance=1.00, tested by Intel on 04/29/2019.

**2S Intel® Xeon® E5-2697 v4 Processor**: 1-node Intel reference platform, 2x Intel® Xeon® E5-2697 v4 processor (2.3GHz, 18C), 8x16GB DDR4-2400, HT on (1 thread/core), Turbo on, 1 SSD SATA, BIOS: SE5C610.86B.01.0028.121720182203, Microcode: 0xb000030, Oracle Linux Server release 7.6 (compatible with RHEL 7.6) on a 7.5 kernel using ksplice for security fixes, Kernel: 3.10.0-957.5.1.el7.crt1.x86_64. HOMME version dungeon28ps://github.com/homme-dycore, WACC benchmark, Intel Parallel Studio XE 2018 Update 3, Intel MPI 2018u3, Relative performance=1.12, tested by Intel on 04/29/2019.

**2S Intel® Xeon® Gold 6148 Processor**: 1-node Intel reference platform, 2x Intel® Xeon® Gold 6148 processor (2.4GHz, 20 cores per socket), 12*16GB DDR4-2666, HT on (1 thread/core), Turbo on, 1 SSD SATA, BIOS: SE5C620.86B.00.01.0016.020120190930, Microcode ver 0x200005c, Oracle Linux Server release 7.6 (compatible with RHEL 7.6) on a 7.5 kernel using ksplice for security fixes, Kernel: 3.10.0-957.5.1.el7.crt1.x86_64. HOMME version dungeon28ps://github.com/homme-dycore, WACC benchmark, Intel Parallel Studio XE 2018 Update 3, Intel MPI 2018u3, Relative performance=1.66, tested by Intel on 04/29/2019.

**2S Intel® Xeon® Platinum 8260 Processor**: 1-node Intel reference platform, 2x Intel® Xeon® 8260 processors (2.4GHz, 24C), 12x16GB DDR4-2933, HT on (1 thread/core), Turbo on, 1 SSD SATA, BIOS: SE5C620.86B.02.01.0008.031920191559, Microcode: 0x400001c, Oracle Linux Server release 7.6 (compatible with RHEL 7.6) on a 7.5 kernel using ksplice for security fixes, Kernel: 3.10.0-957.5.1.el7.crt1.x86_64. HOMME version dungeon28ps://github.com/homme-dycore, WACC benchmark, Intel Parallel Studio XE 2018 Update 3, Intel MPI 2018u3, Relative performance=1.94, tested by Intel on 04/29/2019.

**2S Intel® Xeon® Platinum 9242 Processor**: 1-node Intel reference platform, 2x Intel® Xeon® 9242 processors (2.2GHz, 48C), 24x16GB DDR4-2933, HT on (1 thread/core), Turbo on, 1 SSD SATA, BIOS: SE5C620.86B.0D.01.0456.033120191654, Microcode: 0x4000021, Oracle Linux Server release 7.6 (compatible with RHEL 7.6) on a 7.5 kernel using ksplice for security fixes, Kernel: 3.10.0-957.5.1.el7.crt1.x86_64. HOMME version dungeon28ps://github.com/homme-dycore, WACC benchmark, Intel Parallel Studio XE 2018 Update 3, Intel MPI 2018u3, Relative performance=3.87, tested by Intel on 04/29/2019.
Footnotes and configuration details

STREAM Triad (higher is better):

**2S Intel® Xeon® E5-2697 v3 Processor**: 1-node Intel reference platform, 2x Intel® Xeon® E5-2697 v3 processor (2.6GHz, 14C), 8x16GB DDR4-2133, HT on (1 thread/core), Turbo on, 1 SSD SATA, BIOS: SE5C610.86B.01.0028.121720182203, Microcode: 0x3e, Oracle Linux Server release 7.6 (compatible with RHEL 7.6) on a 7.5 kernel using ksplice for security fixes, Kernel: 3.10.0-957.5.1.el7.crt1.x86_64. Benchmark software: STREAM, Compiler: Intel® Compiler IC19, Optimized libraries: AVX512, Relative performance=1.00, tested by Intel on 02/06/2019.

**2S Intel® Xeon® E5-2697 v4 Processor**: 1-node Intel reference platform, 2x Intel® Xeon® E5-2697 v4 processor (2.3GHz, 18C), 8x16GB DDR4-2400, HT on (1 thread/core), Turbo on, 1 SSD SATA, BIOS: SE5C610.86B.01.0028.121720182203, Microcode: 0xb000030, Oracle Linux Server release 7.6 (compatible with RHEL 7.6) on a 7.5 kernel using ksplice for security fixes, Kernel: 3.10.0-957.5.1.el7.crt1.x86_64. Benchmark software: STREAM, Compiler: Intel® Compiler IC19, Optimized libraries: AVX512, Relative performance=1.14, tested by Intel on 02/06/2019.

**2S Intel® Xeon® Gold 6148 Processor**: 1-node Intel reference platform, 2x Intel® Xeon® Gold 6148 processor (2.4GHz, 20 cores per socket), 12*16GB DDR4-2666, HT on (1 thread/core), Turbo on, 1 SSD SATA, BIOS: SE5C620.86B.00.01.0016.020120190930, Microcode ver 0x2000050, Oracle Linux Server release 7.6 (compatible with RHEL 7.6) on a 7.5 kernel using ksplice for security fixes, Kernel: 3.10.0-957.5.1.el7.crt1.x86_64. Benchmark software: STREAM, Compiler: Intel® Compiler IC19, Optimized libraries: AVX512, Relative performance=1.71, tested by Intel on 02/06/2019.

**2S Intel® Xeon® Platinum 8260 Processor**: 1-node Intel reference platform, 2x Intel® Xeon® Platinum 8260 processors (2.4GHz, 24C), 12x16GB DDR4-2933, HT on (1 thread/core), Turbo on, 1 SSD SATA, BIOS: SE5C620.86B.02.01.0008.031920191559, Microcode: 0x400001c, Oracle Linux Server release 7.6 (compatible with RHEL 7.6) on a 7.5 kernel using ksplice for security fixes, Kernel: 3.10.0-957.5.1.el7.crt1.x86_64. Benchmark software: STREAM, Compiler: Intel® Compiler IC19, Optimized libraries: AVX512, Relative performance=1.89, tested by Intel on 03/03/2019.

**2S Intel® Xeon® Platinum 9242 Processor**: 1-node Intel reference platform, 2x Intel® Xeon® Platinum 9242 processors (2.2GHz, 48C), 24x16GB DDR4-2933, 1 SSD SATA, BIOS: SE5C620.86B.0D.01.0456.033120191654, Microcode: 0x4000021, Oracle Linux Server release 7.6 (compatible with RHEL 7.6) on a 7.5 kernel using ksplice for security fixes, Kernel: 3.10.0-957.5.1.el7.crt1.x86_64. Benchmark software: STREAM, Compiler: Intel® Compiler IC19, Optimized libraries: AVX512, Relative performance=3.59, tested by Intel on 02/26/2019.
Footnotes and configuration details

HPL (higher is better):

2S Intel® Xeon® E5-2697 v3 Processor: 1-node Intel reference platform, 2x Intel® Xeon® E5-2697 v3 processor (2.6GHz, 14C), 8x16GB DDR4-2133, HT on (1 thread/core), Turbo on, 1 SSD SATA, BIOS: SE5C610.86B.01.00028.121720182203, Microcode: 0x3e, Oracle Linux Server release 7.6 (compatible with RHEL 7.6) on a 7.5 kernel using ksplice for security fixes, Kernel: 3.10.0-957.5.1.el7.crt1.x86_64. High Performance Linpack v2.1, compiled with Intel(R) Parallel Studio XE 2019 for Linux, Intel MPI and MKL Version 19.0.1.144, Relative performance=1.00, tested by Intel on 01/30/2019.

2S Intel® Xeon® E5-2697 v4 Processor: 1-node Intel reference platform, 2x Intel® Xeon® E5-2697 v4 processor (2.3GHz, 18C), 8x16GB DDR4-2400, HT on (1 thread/core), Turbo on, 1 SSD SATA, BIOS: SE5C610.86B.01.00028.121720182203, Microcode: 0xb000030, Oracle Linux Server release 7.6 (compatible with RHEL 7.6) on a 7.5 kernel using ksplice for security fixes, Kernel: 3.10.0-957.5.1.el7.crt1.x86_64. High Performance Linpack v2.1, compiled with Intel(R) Parallel Studio XE 2019 for Linux, Intel MPI and MKL Version 19.0.1.144, Relative performance=1.25, tested by Intel on 01/30/2019.

2S Intel® Xeon® Gold 6148 Processor: 1-node Intel reference platform, 2x Intel® Xeon® Gold 6148 processor (2.4GHz, 20 cores per socket), 12x16GB DDR4-2666, HT on (1 thread/core), Turbo on, 1 SSD SATA, BIOS: SE5C620.86B.00.01.0016.020120190930, Microcode ver 0x20000050, Oracle Linux Server release 7.6 (compatible with RHEL 7.6) on a 7.5 kernel using ksplice for security fixes, Kernel: 3.10.0-957.5.1.el7.crt1.x86_64. High Performance Linpack v2.1, compiled with Intel(R) Parallel Studio XE 2018 for Linux, Intel MPI and MKL Version 19.0.1.144, Relative performance=2.37, tested by Intel on 02/06/2019.

2S Intel® Xeon® Platinum 8260 Processor: 1-node Intel reference platform, 2x Intel® Xeon® 8260 Intel processors (2.4GHz, 24C), 12x16GB DDR4-2933, HT on (1 thread/core), Turbo on, 1 SSD SATA, BIOS: SE5C620.86B.02.01.0008.031920191559, Microcode: 0x4000001c, Oracle Linux Server release 7.6 (compatible with RHEL 7.6) on a 7.5 kernel using ksplice for security fixes, Kernel: 3.10.0-957.5.1.el7.crt1.x86_64. High Performance Linpack v2.1, compiled with Intel(R) Parallel Studio XE 2019 for Linux, Intel MPI and MKL Version 19.0.1.144, Relative performance=2.75, tested by Intel on 03/07/2019.

2S Intel® Xeon® Platinum 9242 Processor: 1-node Intel reference platform, 2x Intel® Xeon® 9242 processors (2.2GHz, 48C), 24x16GB DDR4-2933, HT on (1 thread/core), Turbo on, 1 SSD SATA, BIOS: SE5C620.86B.0D.01.0456.033120191654, Microcode: 0x40000021, Oracle Linux Server release 7.6 (compatible with RHEL 7.6) on a 7.5 kernel using ksplice for security fixes, Kernel: 3.10.0-957.5.1.el7.crt1.x86_64. High Performance Linpack v2.1, compiled with Intel(R) Parallel Studio XE 2019 for Linux, Intel MPI and MKL Version 19.0.1.144, Relative performance=5.52, tested by Intel on 03/05/2019.