SOLUTION BRIEF

Intel® Select Solutions
Enterprise Data Center Infrastructure
November 2018

Intel® Select Solutions for BigDL on Apache Spark*

Accelerate and simplify deep learning development and deployment on an optimized, verified infrastructure based on Apache Spark.

Maintaining dedicated graphics processing unit (GPU)–based solutions for deep learning (DL), along with general-purpose CPU solutions, can raise total cost of ownership (TCO). The two solutions can require different expertise and tools to deploy and manage. Beyond management considerations, IT organizations are looking for ways to increase infrastructure utilization. No IT department wants to end up buying too much infrastructure that then goes underutilized. At the same time, no IT organization wants to have too little infrastructure on hand to meet growing demands.

IT organizations are ultimately searching for scalable systems that can easily expand as business demands increase. In addition to growing, IT needs these systems to be able to scale as business grows without re-architecting. Apache Spark* enables this: hundreds of nodes can be added without degrading performance and without changing the fundamental architecture.

Beyond scalability, organizations also seek easier ways to implement artificial-intelligence (AI) initiatives. Many might lack sufficient in-house expertise and infrastructure to get started with AI, particularly for DL. The road to deploying DL in production environments is time-intensive and complex. Managing the data for AI initiatives can also be a challenge: organizations struggle to extract value from their "data swamps," and it can be complex and resource-intensive to move data from on premises to the cloud for analytics.

BigDL

Apache Spark helps solve the challenges for IT of DL, data, and specialized expertise by providing for scalable, standardized big-data storage and compute. Augmenting the storage and compute capabilities of Apache Spark, BigDL—a distributed DL library for Apache Spark—provides efficient, scalable, and optimized DL development on Apache Spark. BigDL provides a distributed DL library for efficient development in an environment based on Apache Spark. It is supported by Analytics Zoo, which provides a unified AI platform and pipeline with built-in reference use cases.

BigDL is optimized for Intel®-based platforms with software libraries like Intel® Math Kernel Library (Intel® MKL) and Intel® Math Kernel Library for Deep Learning Networks (Intel® MKL-DNN) to increase computational performance. Intel® Distribution for Python* accelerates popular machine learning libraries such as NumPy*, SciPy*, and scikit-learn* with integrated Intel® Performance Libraries such as Intel MKL and Intel® Data Analytics Acceleration Library (Intel® DAAL). On the hardware side, Intel® Select Solutions for BigDL on Apache Spark use Intel® Xeon® Gold processors and Intel® Solid State Drives (SSDs) for high performance and improved reliability compared to traditional hard-disk drives (HDDs).

Intel Select Solutions for BigDL on Apache Spark

Intel Select Solutions for BigDL on Apache Spark help optimize price/performance while significantly reducing infrastructure evaluation time. Intel Select Solutions for BigDL on Apache Spark combine Intel Xeon Gold processors, Intel SSDs, and Intel® Ethernet Network Adapters to empower enterprises to quickly harness a reliable, comprehensive solution that delivers:

- **Prepare** your machine learning (ML)/DL infrastructure investments for the future with sca able storage and compute
- **Excellent TCO** with general-purpose hardware that your IT organization is used to managing in a verified, tested solution that simplifies deployment
- **Accelerated time to market** with a turnkey solution that includes a rich development toolset and that is optimized for crucial software libraries
- **The ability to run analytics** on data where it is stored

Hardware Selections

Intel Select Solutions for BigDL on Apache Spark combine the Intel Xeon Gold processor platform, Intel® 3D NAND SSDs, and the Intel® Ethernet 700 Series, so that your business can quickly deploy reliable, BigDL-based DL solutions on a performance-optimized infrastructure.

Intel® Xeon® Gold Processors

Intel Xeon Gold processors provide Intel Select Solutions for BigDL on Apache Spark with an excellent price/performance ratio. Specifically, Intel selected the Intel Xeon Gold 6148 processor to power Intel Select Solutions for BigDL on Apache Spark in order to optimize cost and performance for representative DL workloads while taking into consideration the number of cores and the speed of the processor. Intel Xeon Gold processors provide 2.1x faster AI training and 5.4x faster AI inferencing compared to previous generations of Intel Xeon processors.[1]

Intel® SSD Data Center Family

Storage latency can be a major bottleneck for DL performance. For this reason, Intel Select Solutions for BigDL on Apache Spark use the Intel SSD DC S4500 Series and Intel SSD DC P4510 Series. Based on Intel 3D NAND technology, these enterprise data center SSDs provide a 10x lower annualized failure rate and up to 13x greater transaction performance than HDDs.[2,3]

Intel® Ethernet Connections and Intel® Ethernet Adapters

The Intel Ethernet 700 series accelerates the performance of Intel Select Solutions for BigDL on Apache Spark. These solutions feature Intel Ethernet 700 Series with 10 gigabit Ethernet (GbE) for validated performance ready to meet high quality thresholds for data resiliency and service reliability for most media types and port speeds, and they're backed by extensive testing, validation, and worldwide product support. [4, 5, 6, 7]

What Are Intel® Select Solutions?

Intel Select Solutions are verified hardware and software stacks that are optimized for specific software workloads across compute, storage, and network. The solutions are developed from deep Intel experience with industry solution providers, in addition to extensive collaboration with the world's leading data center and service providers.

To qualify as an Intel Select Solution, solution providers must:

1. Follow the software and hardware stack requirements outlined jointly by Red Hat and Intel (see **Appendix A**)
2. Replicate or exceed Intel's reference benchmark-performance threshold
3. Publish a detailed implementation guide to facilitate customer deployment

Solution providers can develop their own optimizations to add further value to their solutions.

Verified Performance through Benchmark Testing

All Intel Select Solutions are verified through benchmark testing to meet a pre-specified minimum capability level of workload-optimized performance. Intel chose the GoogLeNet* topology running an ImageNet* dataset in order to meet stringent performance standards representative of DL workloads.

GoogLeNet (Inception v1*) won the ImageNet Large Scale Visual Recognition Challenge (ILSVRC) in 2014. ImageNet is a large dataset of more than one million images belonging to multiple classes. This combination of DL topology and image set enables Intel to characterize system-resource utilization for long-running DL training workloads in order to find the optimal configuration for Intel Select Solutions for BigDL on Apache Spark.[8, 9, 10]

Base Configuration

Intel Select Solutions for BigDL on Apache Spark are available in the configuration shown in Appendix A. The "Base" configuration specifies the minimum required performance capability for Intel Select Solutions for BigDL on Apache Spark.

Technology Selections for Intel Select Solutions for BigDL on Apache Spark

In addition to the Intel hardware foundation used for Intel Select Solutions for BigDL on Apache Spark, Intel technologies integrated in Intel Xeon Gold processors deliver further performance and reliability gains:

- **Intel® Volume Management Device (Intel® VMD):** Enables hot-swap replacement of NVM Express* (NVMe*) SSDs from the Peripheral Component Interconnect Express* (PCIe*) bus without shutting down the system, while

Intel® Xeon® Scalable Processors

Intel Xeon Scalable processors:

- Offer high scalability for enterprise data centers
- Deliver performance gains for virtualized infrastructure compared to previous-generation processors
- Achieve exceptional resource utilization and agility
- Enable improved data and workload integrity and regulatory compliance for data center solutions

Intel® Select Solutions for BigDL on Apache Spark* feature Intel Xeon Gold processors.

standardized LED management helps provide much faster identification of SSD status. This standardization brings enterprise reliability, availability, and serviceability (RAS) features to NVMe SSDs, enabling you to deploy next-generation storage with confidence. IT professionals can now service these drives online without an outage, which minimizes interruptions and improves uptime and serviceability. The unique value of Intel VMD is that Intel is sharing this technology across the ecosystem for broad enablement.

- **Intel® Virtual RAID on CPU (Intel® VROC) Technology:** Delivers excellent performance, low power/TCO; supports full-featured RAID levels 0, 1, 5, 10; and is a host bus adapter (HBA)-less RAID solution.
- **Intel® QuickAssist Technology (Intel® QAT):** An offload engine to accelerate some critical workloads such as bulk cryptography, public key exchange, and data compression on Intel architecture–based platforms. Intel QAT on Intel Xeon Gold processors offers outstanding capabilities: up to 100 gigabits per second (Gbps) encryption, 100 Gbps compression, and 100,000 decryption operations per second using a 2,084-bit RSA key.
- **Internet Wide Area Remote Protocol (iWARP) Remote Direct Memory Access (RDMA):** A host-offload, host-bypass technology that enables a secure direct memory-to-memory data communication between two applications across a network. iWARP RDMA can make use of current Ethernet infrastructure without lossless network support. It also provides flow control and congestion management, and it is highly scalable.
- **Intel® Platform Trust Technology (Intel® PTT):** Root of trust with full Trusted Platform Module (TPM) 1.2 functionality integrated into platform firmware. The new Intel PTT feature is available as an option versus a discrete chip to simplify integration and activation.
- **Intel® Boot Guard (Security):** Hardware-based boot integrity protection that prevents unauthorized software and malware takeover of boot blocks critical to a system's function, thus providing an added level of platform security based on hardware.

Deploy an Enterprise-Ready DL Solution with Intel Select Solutions for BigDL on Apache Spark

Intel Select Solutions are a fast path to data center transformation with workload-optimized configurations verified for Intel Xeon Gold processors. When organizations choose Intel Select Solutions for BigDL on Apache Spark, they get pre-tuned and tested configurations that are workload-optimized and proven to scale with Intel Xeon Gold processors so that they can deploy DL solutions quickly and efficiently with less tuning.

Visit intel.com/selectsolutions to learn more, and ask your infrastructure vendor for Intel Select Solutions.

Learn More

Intel Select Solutions: **intel.com/selectsolutions**

Intel Xeon Scalable processors: **intel.com/xeonscalable**

Intel SSD Data Center Family: **intel.com/content/www/us/en/products/memory-storage/solid-state-drives/data-center-ssds.html**

Intel Ethernet 700 Series: **intel.com/ethernet**

Intel Select Solutions are supported by Intel® Builders: **http://builders.intel.com**. Follow us on Twitter: #IntelBuilders

BigDL: **https://software.intel.com/en-us/articles/bigdl-distributed-deep-learning-on-apache-spark**

Appendix A: Base Configuration for Intel Select Solutions for BigDL on Apache Spark

To refer to a solution as an Intel Select Solution, a server vendor or data center solution provider must meet or exceed the defined minimum configuration ingredients and reference minimum benchmark-performance thresholds listed below.

INGREDIENT	INTEL® SELECT SOLUTIONS FOR BIGDL ON APACHE SPARK* **BASE CONFIGURATION**
MINIMUM OF ONE MASTER NODE	
PROCESSOR	Intel® Xeon® Gold 6148 processor (2.40 GHz, 20 cores, 40 threads) or a higher number Intel Xeon Scalable processor
MEMORY	192 GB or higher (12 x 16 GB DDR4-2666)
BOOT DRIVE**	1 x 240 GB or larger Intel® SSD DC S4500 Series (M.2 or 2.5-inch) or higher
STORAGE HBA CONTROLLER PER NODE**	Not applicable (N/A)
DATA TIER	4 x 3.8 TB or larger Intel SSD DC S4500 Series or higher
DATA NETWORK	10 Gb Intel® Ethernet Converged Network Adapter X722
MANAGEMENT NETWORK PER NODE	Integrated 1 GbE port 0/RMM port
MINIMUM OF FOUR WORKER NODES	
PROCESSOR	Intel Xeon Gold 6148 processor (2.40 GHz, 20 cores, 40 threads) or a higher number Intel Xeon Scalable processor
MEMORY	384 GB or higher (12 x 32 GB DDR4-2666)
BOOT DRIVE**	1 x 240 GB or larger Intel SSD DC S4500 Series (M.2 or 2.5-inch) or higher
STORAGE HBA CONTROLLER PER NODE**	N/A
DATA TIER	4 x 960 GB or larger Intel SSD DC S4500 Series or higher
DATA NETWORK	10 Gb Intel Ethernet Converged Network Adapter X722
MANAGEMENT NETWORK PER NODE	Integrated 1 GbE port 0/RMM port
NETWORK SWITCHES	
TOP OF THE RACK (ToR) SWITCH	10 Gbps 48x port switch
MANAGEMENT SWITCH	1 Gbps 48x port switch
SOFTWARE	
LINUX OS	CentOS* Linux* release 7.5.1804 or Red Hat* Enterprise Linux (RHEL*) 7
APACHE SPARK	2.2.0
APACHE HADOOP*	2.7.3
JAVA DEVELOPMENT KIT* (JDK*)	Oracle* JDK 1.8.0 update 181 or later
BIGDL	0.6
ANALYTICS ZOO	0.2
INTEL® DISTRIBUTION FOR PYTHON*	2.7
INTEL® MATH KERNEL LIBRARY (INTEL® MKL)	Intel MKL version 2018 Update 3
APPLIES TO ALL NODES	
TRUSTED PLATFORM MODULE (TPM)	TPM 1.2 discrete or firmware TPM (Intel® Platform Trust Technology [Intel® PTT])

FIRMWARE AND SOFTWARE OPTIMIZATIONS	Intel® Volume Management Device (Intel® VMD) enabled** Intel® Boot Guard enabled** Intel® Hyper-Threading Technology (Intel® HT Technology) disabled Intel® Turbo Boost Technology enabled P-states enabled** C-states enabled** Power-management settings set to performance** Workload configuration set to balanced** Memory Latency Checker (MLC) streamer enabled** MLC spatial prefetch enabled** Data Cache Unit (DCU) data prefetch enabled** DCU instruction prefetch enabled** Last-Level Cache (LLC) prefetch disabled** Uncore frequency scaling enabled**

MINIMUM PERFORMANCE STANDARDS

Verified to meet or exceed the following minimum performance capabilities:

IMAGENET* TRAINING THROUGHPUT	375 images per second with Top-5 Accuracy of 85% or higher

**Recommended, not required

[1] Intel. Intel® Optimization for Caffe ResNet-50* performance does not necessarily represent other framework performance. Based on Intel internal testing: 1x (July 11, 2017), 1.4x (August 2, 2018), and 5.4x (July 26, 2018) performance improvement based on Intel® Optimization for Caffe ResNet-50 inference throughput performance on Intel® Xeon® Scalable processors. Performance results are based on testing as of July 11, 2017 (1x), August 2, 2018 (1.4x), and July 26, 2018 (5.4x) and may not reflect all publicly available security updates.

July 11, 2017 details: (Previous-generation processor) 2S Intel Xeon processor E5-2699 v4 at 2.20 GHz (22 cores), Intel® Hyper-Threading Technology (Intel® HT Technology) enabled, Intel® Turbo Boost Technology disabled, scaling governor set to "performance" via acpi-cpufreq driver, 256 GB DDR4-2133 ECC RAM. CentOS* Linux* release 7.3.1611 (core), Linux kernel 3.10.0-514.10.2.el7.x86_64. SSD: Intel® SSD DC S3500 Series (480 GB, 2.5-in Serial ATA [SATA], 6 gigabits per second [Gbps], 20 nanometer [nm], Memory Latency Checker [MLC]). (Current-generation processor) 2S Intel Xeon Platinum 8180 processor at 2.50 GHz (28 cores), Intel HT Technology disabled, Intel Turbo Boost Technology disabled, scaling governor set to "performance" via intel_pstate driver, 384 GB 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 (800 GB, 2.5-in SATA, 6 Gbps, 25 nm, MLC). Performance measured with environment variables set to: KMP_AFFINITY='granularity=fine, compact', OMP_NUM_THREADS=56, CPU frequency set with cpupowerfrequency-set -d 2.5G -u 3.8G -g performance. Caffe framework details: revision f96b759f71b2281835f690af267158b82b150b5c. Inference measured with "caffetime --forward_only" command, training measured with "caffetime" command. For "ConvNet" topologies, dummy dataset was used. For other topologies, data was stored on local storage and cached in memory before training. Topology specs from https://github.com/intel/caffe/tree/master/models/intel_optimized_models (GoogLeNet*, AlexNet*, and ResNet-50), https://github.com/intel/caffe/tree/master/models/default_vgg_19 (VGG-19), and https://github.com/soumith/convnet-benchmarks/tree/master/caffe/imagenet_winners (ConvNet benchmarks; files were updated to use newer Caffe prototxtformat).

August 2, 2018 details: 2S Intel Xeon Platinum 8180 processor at 2.50 GHz (28 cores), Intel HT Technology enabled, Intel Turbo Boost Technology enabled, 376 GB DDR4-2666 ECC RAM, resnet_50_v2 topology. Engine: Intel® Math Kernel Library for Deep Neural Networks (Intel® MKL-DNN) version 464c268e544bae26f9b85a2acb9122c766a4c396.

July 26, 2018 details: 2S Intel Xeon Platinum 8180 processor at 2.50GHz (28 cores), Intel HT Technology enabled, Intel Turbo Boost Technology enabled, 192 GB DDR4-2666 ECC RAM, best (resnet--50, gnet_v3 --224, ssd--224) topology. Caffe framework details: inference measured with "caffe time --forward_only -phase TEST" command, training measured with "caffe train" command. Environment variables: KMP_AFFINITY='granularity=fine, compact,1,0', OMP_NUM_THREADS=28, CPU frequency set with cpupowerfrequency-set -d 2.5G -u 3.8G -g performance. Caffe run with "numactl-l".

[2] Intel. Intel SSD Annualized Fail Rate Report for all of 2016.

[3] Intel: Performance data based on IOMeter* 2014. Configuration: ASUSTeK Computer Inc. H871-Plus*; Intel® Core™ i7-4770 processor (LGA1150, 3.4 GHz, 8 MB, 84 W, 4 cores); heat sink: Intel® E97378-001 Lga1155/1156; memory: 4 GB DDR3 1333 PC3-10600 (667 MHz) Kingston*; 480 GB Intel® SSD DC S3510 Series and Seagate* Savio* 10K SAS ST300MM006 hard drive; Mini-ITX Antec* chassis; 350 W power supply.

[4] The Intel® Ethernet 700 Series includes extensively tested network adapters, accessories (optics and cables), hardware, and software, in addition to broad operating system support. A full list of the product portfolio's solutions is available at intel.com/ethernet. Hardware and software is thoroughly validated across Intel® Xeon® Scalable processors and the networking ecosystem. The products are optimized for Intel® architecture and a broad operating system ecosystem: Windows*, Linux* kernel, FreeBSD*, Red Hat* Enterprise Linux (RHEL*), SUSE*, Ubuntu*, Oracle Solaris*, and VMware ESXi*.

[5] The Intel® Ethernet 700 Series is backed with global support infrastructure for customers pre- and post-sales.

[6] Supported connections and media types for the Intel® Ethernet 700 Series are: direct-attach copper and fiber SR/LR (QSFP+, SFP+, SFP28, XLPPI/CR4, 25G-CA/25G-SR/25G-LR), twisted-pair copper (1000BASE-T/10GBASE-T), backplane (XLAUI/XAUI/SFI/KR/KR4/KX/SGMII). Note that Intel is the only vendor offering the QSFP+ media type.

[7] The Intel® Ethernet 700 Series supported speeds include 10 GbE, 25 GbE, 40 GbE, and 100 GbE.

[8] Olga Russakovsky*, Jia Deng*, Hao Su, Jonathan Krause, Sanjeev Satheesh, Sean Ma, Zhiheng Huang, Andrej Karpathy, Aditya Khosla, Michael Bernstein, Alexander C. Berg and Li Fei-Fei. (* = equal contribution) ImageNet Large Scale Visual Recognition Challenge. IJCV, 2015. http://www.image-net.org/challenges/LSVRC/.

[9] Szegedy, Christian, Liu, Wei, Jia, Yangqing, et al. "Going deeper with convolutions." arXiv.org. September 2014. https://arxiv.org/pdf/1409.4842.pdf.

[10] ImageNet. About ImageNet page. http://image-net.org/about-overview.

Performance results are based on testing as of October 10, 2018and 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. For more complete information visit intel.com/benchmarks.

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Intel does not control or audit third-party benchmark data or the web sites referenced in this document. You should visit the referenced web site and confirm whether referenced data are accurate.

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