White Paper

Sustainability
4th Gen Intel® Xeon® Scalable Processors

Increase Efficiency in the Data Center for Sustainable Computing

Achieve up to 14 percent less energy use at 1.5x larger bandwidth through optimized energy-efficiency improvements in next-generation SK hynix DDR5 memory on 4th Gen Intel Xeon Scalable processors.[1]

Accelerate the sustainable data center

Data centers today consume a large amount of energy. Data centers and data-transmission networks consume about 1 to 1.5 percent of global electricity, and this consumption is expected to rise.[2] The rapid growth in workloads in large data centers has increased energy use by 10 to 30 percent per year over the past several years, according to the International Energy Agency (IEA).[2]

As a result, many data centers are adopting sustainable technologies and practices to reduce their environmental impact. The latest technologies from Intel and SK hynix can help improve energy efficiency in data centers and help achieve green energy goals. 4th Gen Intel Xeon Scalable processors, Intel's most sustainable data center processor, have a range of features for managing power and performance. These processors can provide higher memory bandwidth and scaling capacity, compared to the previous generation, with SK hynix DDR5 SDRAM as their main memory. This better bandwidth and scalability are bolstered by SK hynix DDR5 improvements over DDR4 for lower total cost of ownership (TCO) and a 14 percent smaller power footprint.[3]

Built-in accelerators help drive energy efficiency

4th Gen Intel Xeon Scalable processors are designed to make efficient use of other resources on the motherboard to save power and help enterprises achieve sustainability goals. The processors can help accelerate performance across the fastest-growing workloads—including artificial intelligence (AI), analytics, networking, security, and high-performance computing (HPC). They feature architecture with higher per-core performance than the previous generation, in addition to built-in acceleration.

Organizations can achieve up to a 2.9x average performance-per-watt efficiency improvement for target workloads utilizing built-in accelerators, compared to the previous generation of processors.[4] Built-in acceleration can lead to more efficient CPU utilization, lower electricity consumption, and higher return on investment (ROI). The platform features accompanying advances in memory and input/output (I/O) subsystems, providing up to 4,800 megatransfers per second (MT/s) (with 1 DIMM per channel) or 4,400 MT/s (with 2 DIMMs per channel) with DDR5 memory.[5]

DDR5 technology: Improved performance, capacity, and efficiency

In addition to supporting the overall performance of 4th Gen Intel Xeon Scalable processors, SK hynix DDR5 SDRAM offers significant performance, capacity, and power-efficiency improvements of its own over DDR4 technology.

Performance

SK hynix measured the effective bandwidth of DDR4 memory and compared it to DDR5 in an 8-channel DIMM configuration. Using DDR4 memory with a maximum bandwidth of up to 3,200 megabits per second (Mbps) as the baseline, DDR5 was able to deliver 20 percent more effective bandwidth (Figure 1).[1,6] In addition, DDR5 SDRAM operating at 4,800 Mbps can provide up to 70 percent greater effective bandwidth than the DDR4 SDRAM operating at 3,200 Mbps.[1,6] This increase in effective bandwidth is driven by structural enhancements because of the increase in the total number of banks and bank groups and an increase in the burst length from 8 (BL8) to 16 (BL16).

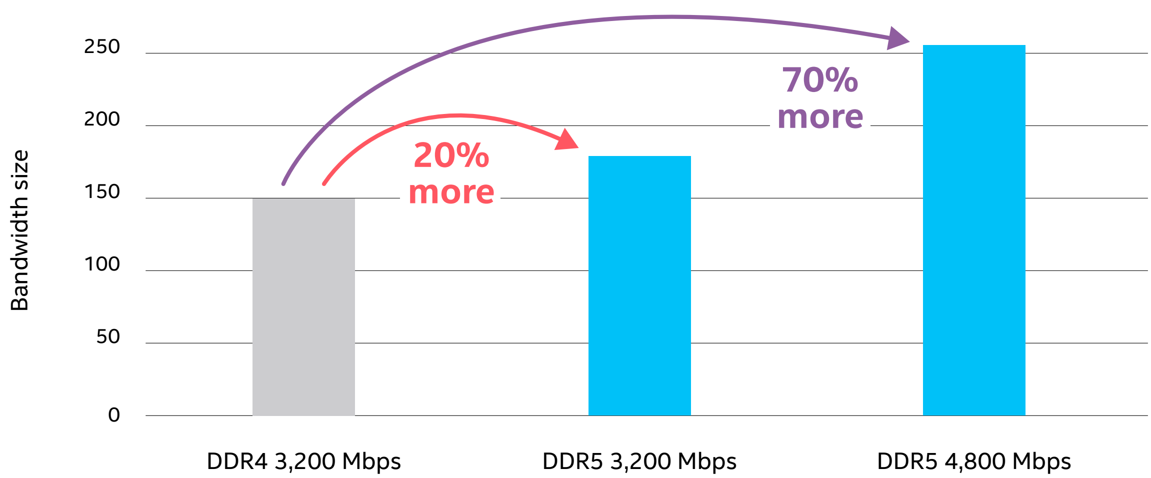

Figure 1. Effective bandwidth of DDR4 compared to DDR5 memory[1,6]

Capacity

The increased burst length from 8 in DDR4 memory to 16 in DDR5 memory doubles the data bus efficiency. This provides an up to 50 percent reduction in the number of reads/writes to access the same cache data line. The increase in burst length also improves command/address and data-bus efficiency, and it enables DDR5 SDRAM to have two separate subchannels.

In addition to an increase in memory density, the number of bank groups in DDR5 memory increased compared to DDR4, leading to a higher total number of banks. Having more bank groups allows shorter interleaved timing access, thus helping to prevent performance degradation.

The enhanced signal integrity of the DDR5 interface has led to higher data rates. In addition, DDR5 adopts several new features that attenuate the effect of inter-symbol interference or that adjust for signal reduction from channel loss. These and other enhanced capabilities can help nearly double the effective bandwidth of DDR5 compared to DDR4, with transmission rates ranging from at least 4,800 Mbps to up to 8,000 Mbps.[7]

Power efficiency

The introduction of a power management integrated circuit (PMIC) in DDR5 memory is probably one of the biggest changes from DDR4. Whereas DDR4 power was controlled on the motherboard, DDR5 power is managed on the DIMM itself, thus enabling better voltage regulation.

The starting bandwidth of DDR5 is 1.5x greater than that of DDR4, with more aggregate module power when factoring in PMIC power. Energy use, however, is reduced 10 to 20 percent in DDR5 modules due to lower operating voltages (from 1.2 V to 1.1 V) and improved DRAM architecture. As seen in Figure 2, DDR5 memory requires as much as 14 percent less energy at 1.5x higher bandwidth.[1,8]

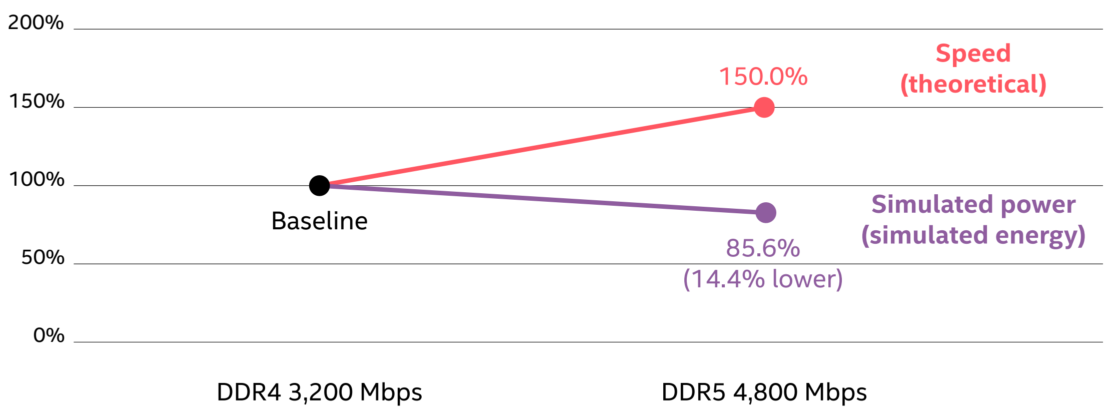

Figure 2. DDR5 speed and energy use compared to that of DDR4[1,8]

Generation-over-generation improvements evident in benchmark testing

To provide a better understanding of how much performance was improved from 3rd Gen Intel Xeon Scalable processors to 4th Gen Intel Xeon Scalable processors, SK hynix conducted several benchmark tests to see how the processors compared in overall bandwidth, compute performance, and database workload performance. Table 1 describes the configurations for this testing.

Table 1. SK hynix test configurations

Component	3rd Gen Intel Xeon Scalable Processor	4th Gen Intel Xeon Scalable Processor
CPU	Intel Xeon Platinum 8380 processor at 2.30 GHz	Intel Xeon Platinum 8470 processor at 2.00 GHz (pre-production)
Memory	256 GB (8 x 32 GB DDR4 3,200 MT/s)	256 GB (8 x 32GB DDR5 4,800 MT/s)
Network interface controller (NIC)	2 x Intel® Ethernet Controller X710 for 10GBASE-T	2x 10 gigabit Ethernet (GbE) Intel Ethernet Controller X550T
Disk	1 x 2.6 TB RSP3TD160F, 1 x 931.5 GB SHPP41-1000GM	1 x 931.5 GB SHPP41-1000GM
Operating system (OS)	Ubuntu 22.04 LTS	Ubuntu 22.04 LTS
Thermal design power (TDP)	270 W	350 W

Bandwidth and benchmarking tools

SK hynix used the following tools in the analysis:

- **Intel® Memory Latency Checker (Intel® MLC)** helps measure memory latency and bandwidth.
- **SPEC CPU 2017** contains next-generation, industry-standardized, CPU-intensive suites for measuring and comparing compute-intensive performance and for stressing a system's processor, memory subsystem, and compiler. This benchmark provides a standard to measure, analyze, and compare computing performance. The integer rate (intrate) workload consists of integer calculation suites and the floating point (fprate) workload consists of floating-point suites.
- **Redis-bench** measures the performance of Redis database workloads.
- **Yahoo! Cloud Service Benchmark (YCSB)** provides a framework and common set of workloads for evaluating the performance of different key-value and cloud serving stores. In the testing, SK hynix used YCSB to measure Redis database direct read/write workloads.

Intel MLC results

With its improved performance and capacity, DDR5 alleviates the need for additional memory bandwidth compared to DDR4 memory. Based on simple calculations of maximum bandwidth for systems populated with 8 channels (1 DIMM per channel), DDR5 modules provide a 50 increase in bandwidth compared to DDR4. In addition, fewer modules are needed for greater memory bandwidth. For example, when a bandwidth of 200 GB/s is required, 10 DDR4 modules might be required, as opposed to seven or eight DDR5 modules.

SK hynix ran Intel MLC testing using several workload types: 1R (100 percent read), 3R1W (75 percent read and 25 percent write), 2R1W (67 percent read and 33 percent write), 1R1W (50 percent read and 50 percent write), and a STREAM Triad benchmark. The STREAM benchmark is a simple, synthetic benchmark designed to measure sustainable memory bandwidth (in MB/s) and a corresponding computation rate for four simple vector kernels: Copy, Scale, Add, and Triad. Of all the vector kernels, Triad is the most complex scenario and is highly relevant to HPC.

As shown in Figure 3, SK hynix's testing results demonstrated that the 4th Gen Intel Xeon Scalable processor–based platform obtained 1.40x bandwidth for 1R workloads and 1.51x bandwidth for 1R1W workloads, compared to the 3rd Gen Intel Xeon Scalable processor–based platform.[1] This improvement in bandwidth is likely due to the improvement in performance by transitioning from DDR4 to DDR5.

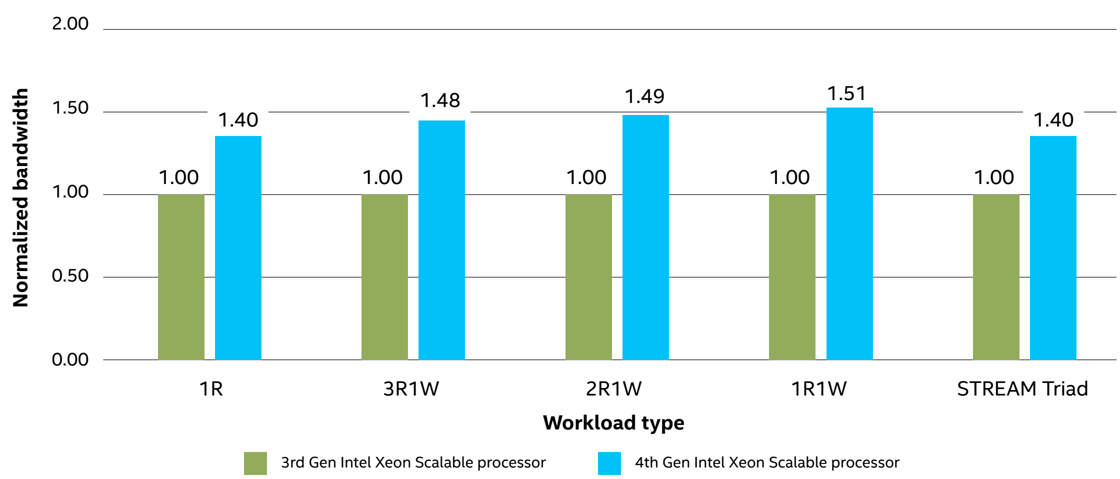

Figure 3. Normalized bandwidth measured with Intel MLC[1]

SPEC CPU 2017

As seen in Figure 4, average performance improved 1.59x, as measured by the SPEC CPU 2017 intrate workload, and 1.43x using the SPEC CPU 2017 fprate workload for the 4th Gen Intel Xeon Scalable processor–based platform, compared to the 3rd Gen Intel Xeon Scalable processor–based platform in SK hynix's testing.[1]

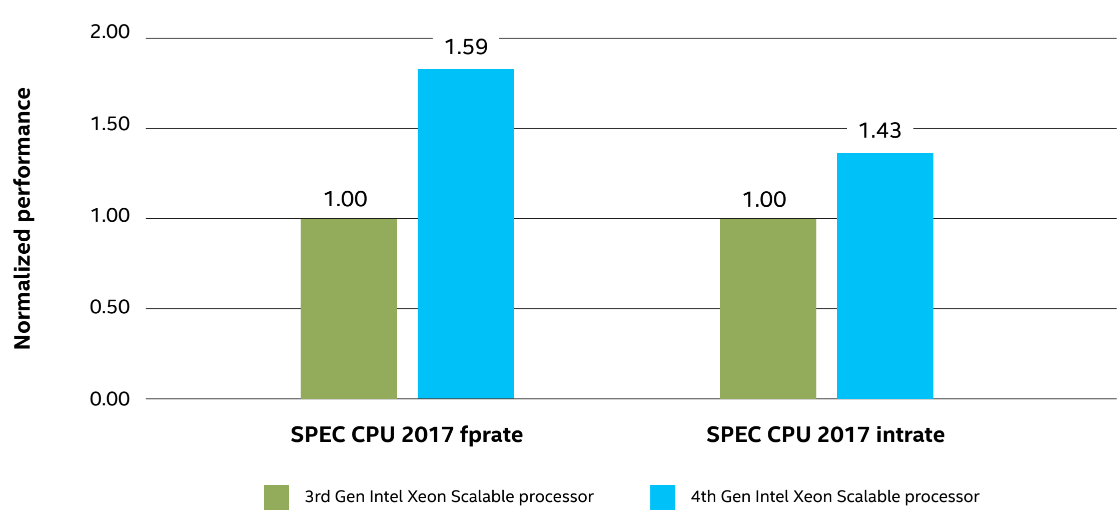

Figure 4. Normalized performance using SPEC CPU 2017 fprate and intrate (estimates)[1]

Figure 5 presents the results of normalized performance per total power consumption in SK hynix's testing, a metric obtained by dividing throughput by overall power consumption when performing a given task. As a result, the engineers observed that energy efficiency improved by 1.22x on the 4th Gen Intel Xeon Scalable processor–based platform with SPEC CPU 2017 intrate and 1.11x with SPEC CPU 2017 fprate, compared to the 3rd Gen Intel Xeon Scalable processor–based platform.[1] This means that when running a program comparable to SPEC CPU 2017 intrate, 4th Gen Intel Xeon Scalable processor–based platforms can deliver up to 22 percent more performance while consuming the same power as previous-generation processor–based platforms.[1]

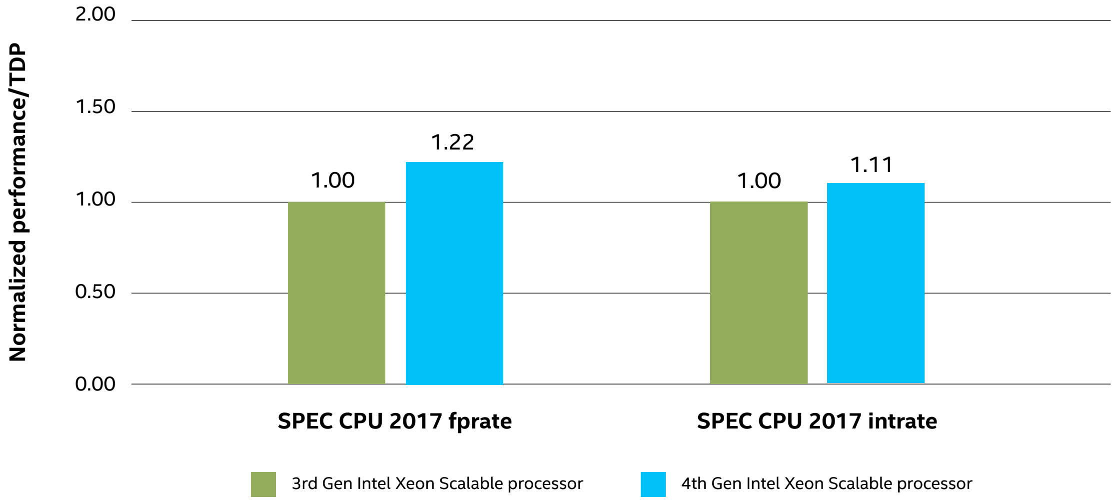

Figure 5. Normalized performance per total power consumption using SPEC CPU 2017 fprate and intrate[1]

Redis-bench and YCSB

Figures 6 and 7 present the normalized throughput of Redis SET and GET workloads. Redis-bench testing on the 4th Gen Intel Xeon Scalable processor–based platform showed throughput improvements of 1.16x and 1.14x for SET and GET, respectively, compared to the 3rd Gen Intel Xeon Scalable processor–based system.[1,9]

Redis performance measured with YCSB also improved on the 4th Gen Intel Xeon Scalable processor–based platform, as seen in Figure 7. Throughput improved 1.19x in a workload of 100 percent insert operations. In addition, throughput improved 1.26x in the run workload comprising 3/4 read and 1/4 update operations.[1,9]

The results indicate another benefit of reducing data center space requirements through server consolidation and accompanying costs. On a platform with 3rd Gen Intel Xeon Scalable processors, Redis requires six CPUs to process a run operation of 6 Mbps, but a platform with 4th Gen Intel Xeon Scalable processors requires only four CPUs.

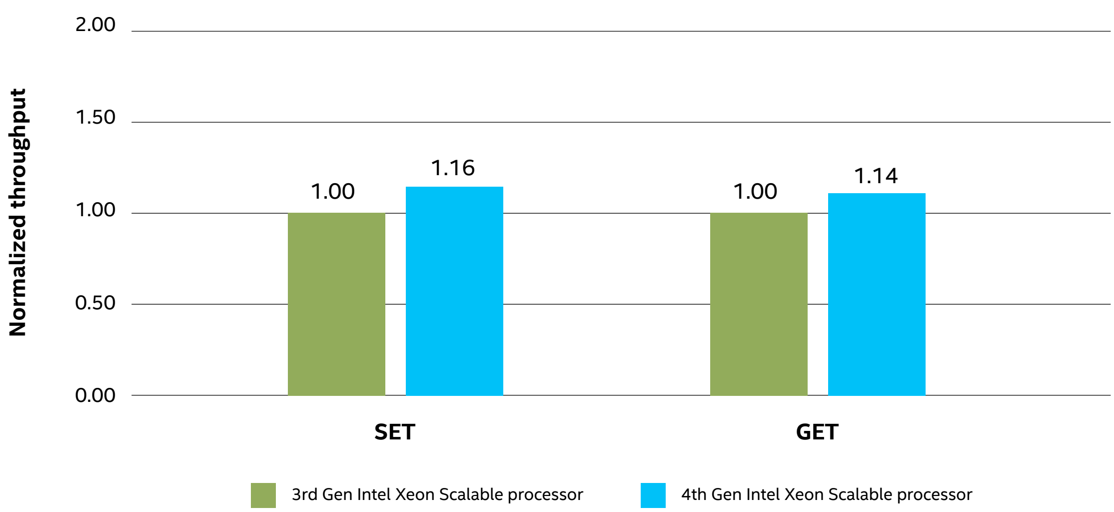

Figure 6. Normalized throughput using Redis-benchmark 8 tread (SET and GET)[1,9]

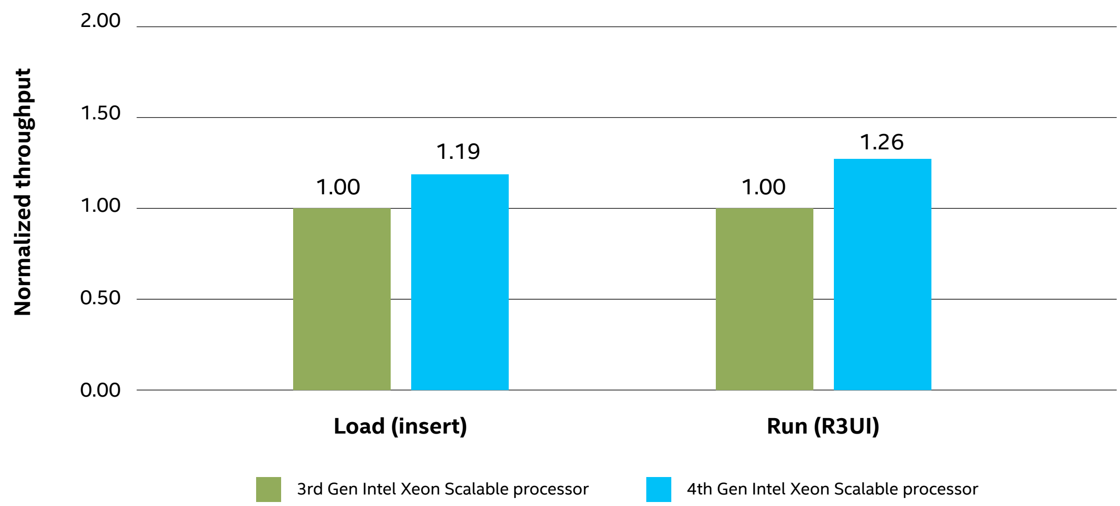

Figure 7. Normalized throughput using Redis with YCSB 8 thread (load and run)[1,9]

Improve power consumption and performance with Intel and SK hynix

Many data centers today are adopting a wide range of sustainable technologies and practices. Intel and SK hynix are leading the way with their latest technologies designed to improve energy efficiency. 4th Gen Intel Xeon Scalable processors and SK hynix DDR5 SDRAM provide higher memory bandwidth and scaling capacity, better performance, and a smaller power footprint than previous-generation technologies. Together, these advancements are critical in helping accelerate the transition toward sustainable data centers and reducing the environmental impact of critical infrastructure.

Learn more about 4th Gen Intel Xeon Scalable processors and the SK hynix DRAM ecosystem.

1 **3rd Gen Intel Xeon Scalable processor–based baseline system**: Tested by SK hynix as of 4/8/2022. 1-node, 2 x Intel Xeon Platinum 8380 processor at 2.30 GHz, 40 cores, Intel® Hyper-Threading Technology (Intel® HT Technology) off, Intel® Turbo Boost Technology on, 256 GB total memory (8 x 32 GB DDR4 3,200 MT/s [3,200 MT/s]), BIOS SE5C620.8 6B.01.01.0006.2207150335, microcode 0xd000375, 2 x 10 Intel Ethernet Controller X710 for 10GBASE-T, 1 x 2.6 TB RSP3TD160F, 1 x 931.5 GB SHPP41-1000GM, Ubuntu 22.04 LTS, 5.15.0-56-generic, gcc 11.3.0 gfortan 11.3.0, SPEC CPU2017 intrate/fprate, Intel MLC peak_injection_bandwidth, Intel MLC 3.9a, Redis 6.2.1 (1 client [32 clients], 1 server [8 redis-server instances]), YCSB 0.17.0 (Load > Insert: 100%, Run > read : update=3 :1). **4th Generation Intel Xeon Scalable processor–based system**: Tested by SK hynix as of 4/3/2023. 1-node, 2 x Intel Xeon Platinum 8470 processor at 2.00 GHz (pre-production), 52 cores, Intel HT Technology off, Intel Turbo Boost Technology on, 256 GB total memory (8 x 32 GB DDR5 4,800 MT/s [3,200 MT/s]), BIOS 1.0a (pre-production), microcode 0x2b000081 (pre-production), 2 x 10 GbE Intel Ethernet Controller X550T, 1 x 931.5 GB SHPP41-1000GM, Ubuntu 22.04 LTS, 5.15.0-56-generic, gcc 11.3.0 gfortan 11.3.0, SPEC CPU2017 intrate/fprate, Intel MLC peak_injection_bandwidth, Intel MLC 3.9a, Redis 6.2.1 (1 client [32 clients], 1 server [8 redis-server instances]), YCSB 0.17.0 (Load > Insert: 100%, Run > read: update=3 : 1).

2 International Energy Agency (IEA). "Data Centres and Data Transmission Networks." September 2022. iea.org/reports/data-centres-and-data-transmission-networks. License: CC BY 4.0.

3 Simulated value by SK hynix as of December 2022.

4 As measured by energy efficiency testing (performance/watt) by Intel as of November 2022. For full workloads and configuration details, visit intel.com/PerformanceIndex (4th Gen Intel Xeon Scalable processors, E1).

5 As measured by STREAM Triad testing by Intel as of September 9, 2022, and August 13, 2022. For full workloads and configuration details, visit intel.com/PerformanceIndex (4th Gen Intel Xeon Scalable processors, G2).

6 Bandwidth was tested under the following conditions: 64 B random access, 75 percent read (3:1 read/write ratio), 2RX8, 16 Gb. DDR5 4,800 Mbps improvement range at DDR4 3,200 Mbps bus efficiency: DDR5 +70 percent at DDR4 75 percent, ~DDR5 +87 percent at DDR4 67 percent.

7 SK hynix Global. "Search for the Next-generation Memory, DDR5." May 2021. https://youtu.be/o3zAgsW_8RA.

8 1.5x higher bandwidth: 4,800 Mbps (of the DDR5) divided by 3,200 Mbps (of the DDR4). 14.4 percent less energy: Comparison of DDR4 and DDR5 results simulated by SK hynix's power calculator.

9 Notes for Redis 6.2.1: Memtier benchmark for Redis was not used. Ran redis-bench included in Redis 6.2.1. SET=100 percent write; GET=100 percent read.

For your vision of upcoming DRAM ecosystem. Learn more at product.skhynix.com/support/downloads/kits.go.

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