Containerized Application Kernels on Google Cloud

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As a part of a public cloud evaluation, we ran containerized application kernels on Google Cloud. Three different virtual machines (VM) were selected (Table 1): 1) general-purpose CPU with 8 cores, 2) Intel Cascade Lake generation CPU with AVX-512 and with 40 physical cores, and 3) AMD Zen-2 generation CPU with 112 physical cores. The first VM represents a reasonably sized machine for a permanent presence online. The other two represent high compute-capable resources. For the comparison, we use 8 core virtual machines from the Aristotle Cloud Federation (https://federatedcloud.org/) and several XSEDE HPC systems (Table 2).

Table 1. Used Google Cloud virtual instances configurations. Note that Google Cloud uses hyper-threading (HT) cores for core counting, whereas here we count physical cores

Configuration Name	Physical Cores	CPU Family	Machine Type	Disk Type	Estimated Price, $/ Month
Google-Cloud-8core	8	Intel Haswell+	e2-highcpu-16	pd-balanced	147.45
Google-Cloud-40core	40	Intel Cascade Lake	n2-highcpu-80	pd-balanced	1,678.24
Google-Cloud-112core	112	AMD Zen 2	n2d-highcpu-224	pd-balanced	4,083.91
Google-Cloud-8core-FastStorage	8	Intel Haswell+	e2-highcpu-16	pd-ssd	149.55

Table 2. Google Cloud and Aristotle Cloud VMs, as well as other systems where application kernels were executed.

Resource	Resource Type	Physical Cores	Resource Provider	CPU Family
Google-Cloud-8core	Cloud	8	Google	Intel Haswell+
Google-Cloud-40core	Cloud	40	Google	Intel Cascade Lake
Google-Cloud-112core	Cloud	112	Google	AMD Zen 2
Cornell-redcloud	Cloud	8	Cornel U.	Intel Haswell+
UB-lakeeffect	Cloud	8	UB	Intel Haswell+
UCSB-overcloud	Cloud	8	UCSB	Intel Haswell+
comet	HPC	24	SDSC	Intel Haswell
bridges	HPC	28	PSC	Intel Haswell
stampede2-skx	HPC	48	TACC	Intel Skylake-X
Bridges-2	HPC	128	PSC	AMD Zen 2
Expanse	HPC	128	SDSC	AMD Zen 2

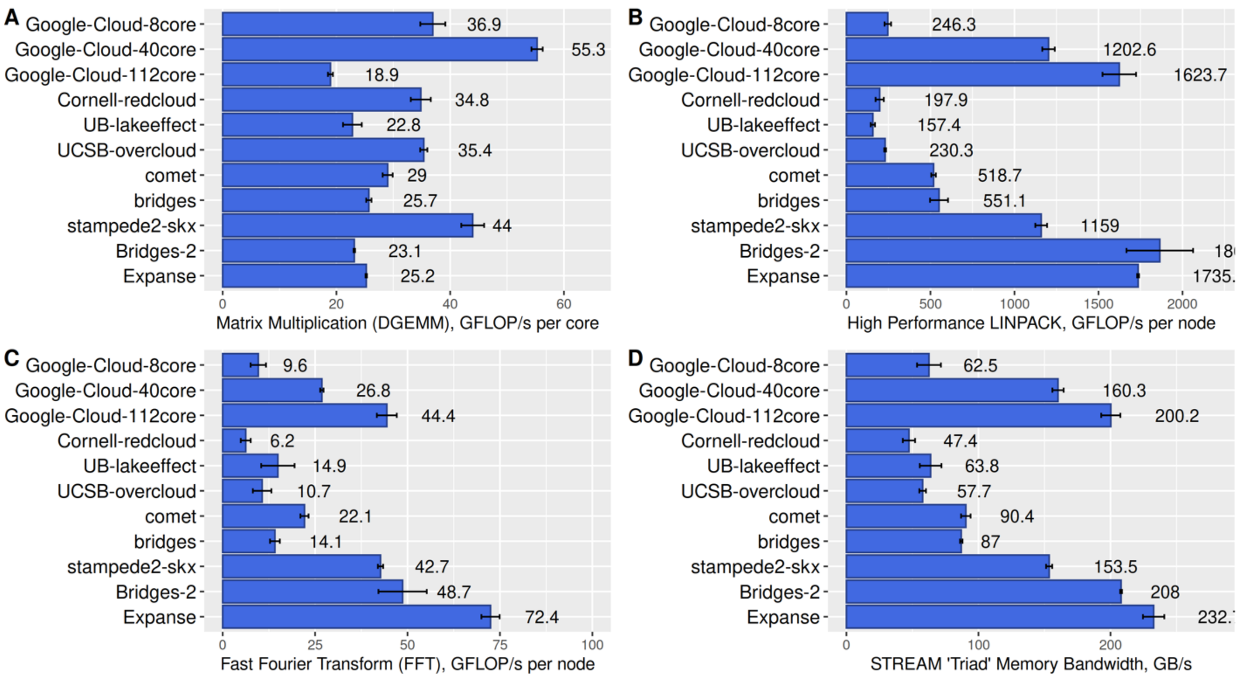

Figure 1. HPCC Benchmark. A. Matrix-Matrix Multiplication. B. LINPACK. C. FFT performance. D. Memory bandwidth.

HPCC is a benchmark suite combining several well-known tests under one package. The selected metrics are shown in Figure 1. The performance of 8-core VMs in Google Cloud and Aristotle Cloud are very similar, with Google Cloud slightly faster. For more compute powerful VMs, the performance is comparable to their counterparts in XSEDE systems. For example, Google Cloud 40 cores VM shows the highest matrix-matrix multiplication per core due to wider SIMD instructions (AVX512) available on that system. TACC Stampede2 SKX system has a 20% slower matrix-matrix multiplication performance; this system is also AVX512 capable but is based on older CPU generation and probably has a slower base clock. In the per-core performance, Google Cloud 112 cores VM is very similar to Bridges-2 and Expanse. These three systems utilize the same generation CPU (AMD Zen 2) and are only different by core counts and base clocks (Bridges-2 and Expanse have the same CPU model). Per-node performance is smaller on Google Cloud 112 cores VM due to smaller core count. HPCG shows similar outcomes as HPCC (Figure 2). Importantly the performance variability for Google Cloud is comparable to Aristotle Cloud and XSEDE HPC resources.

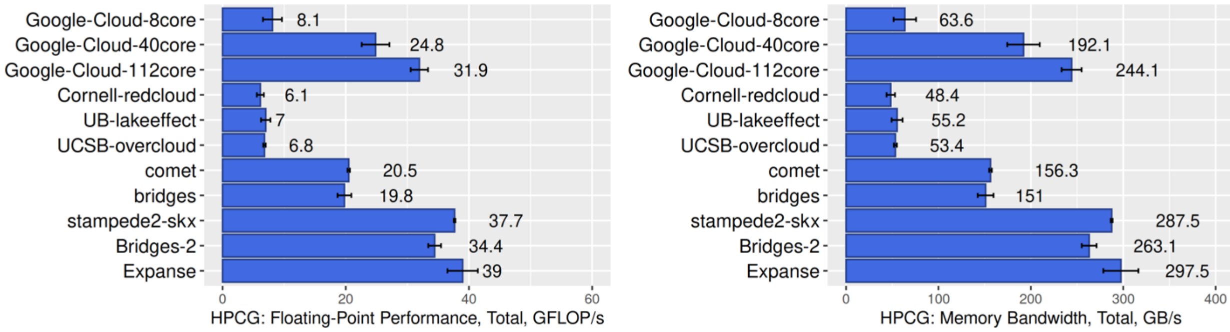

Figure 2. HPCG. Note that on TACC-Stampede2 SKX an Intel optimized version of HPCG were used.

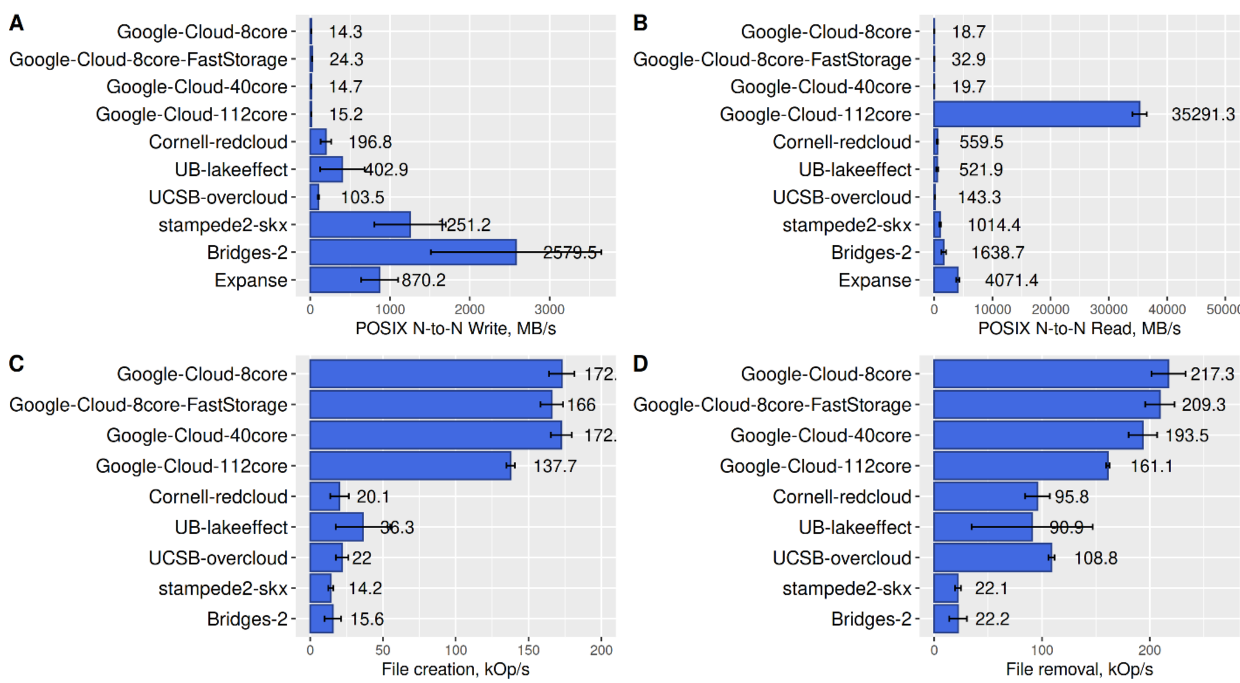

Figure 3. Filesystem IO benchmarking by IOR, measuring bandwidth (A and B) and MDTest, measuring metadata operations (C and D). Measuring filesystem IO is difficult due to disk caching, which hides the low performance of underlying hardware and overestimates the performance measurements. There are several ways to lower the effects of caching. On the HPC system, file writing and reading occurs on a different node. Because our Cloud benchmarks use only one VM instance, such a technique cannot be used. So, the disk cache was dropped within VM (require root privileges), but it is unclear how it affects caching on an actual physical machine.

The Google Cloud filesystem IO bandwidth is moderate for both balanced and SSD persistent storage. The latter doubles the performance, but it is still lower than Aristotle Cloud values, or XSEDE HPC resources. The metadata operations, on the other hand, are significantly better on Google Cloud.

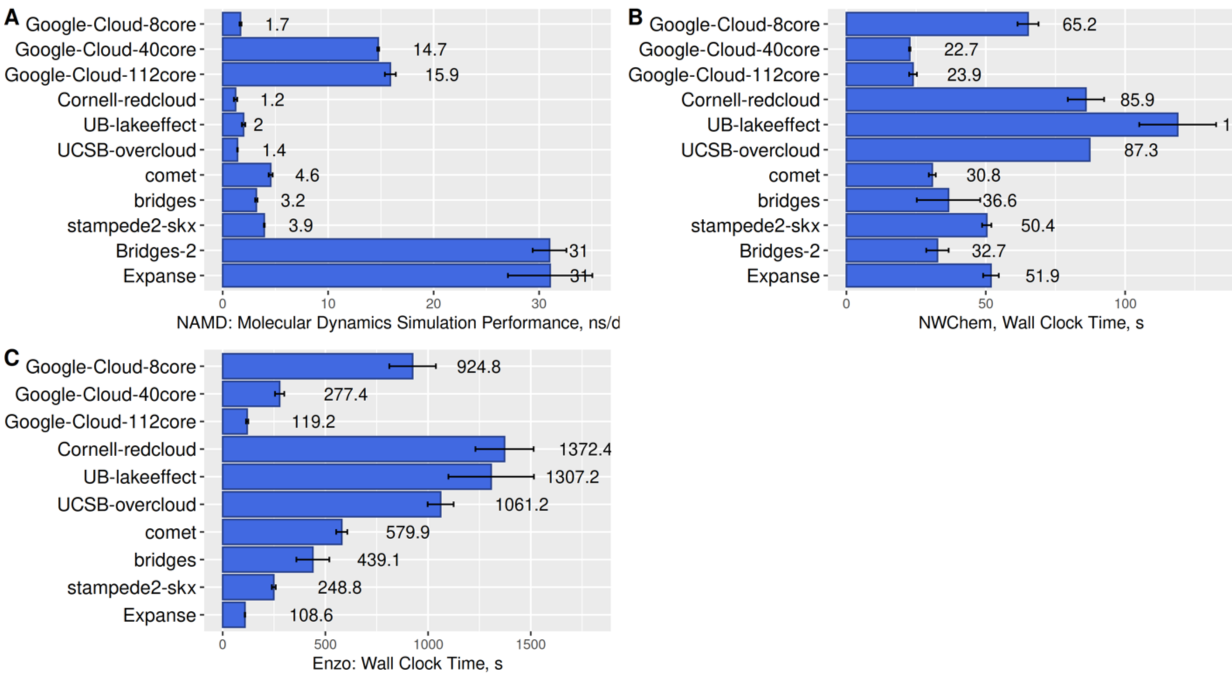

Figure 4. The performance in scientific applications. A. simulation speed in NAMD (higher value is better). B NWChem execution wall time (smaller is better) and C. Enzo execution wall time (smaller is better).

The results from pure benchmarks translate well to the performance in real applications. The performance of Google Cloud in real applications is well in the range of other platforms, especially if one compares platforms with similar computational capabilities. The 8-core machine is almost always better than a similar configuration from Aristotle Cloud. Newer and more compute-capable VMs (40 and 112 cores) have better performance than comparable systems (Bridges-2 and Expanse) in NWChem but are slower in NAMD and Enzo. In all cases, the performance is similar in size and variability.

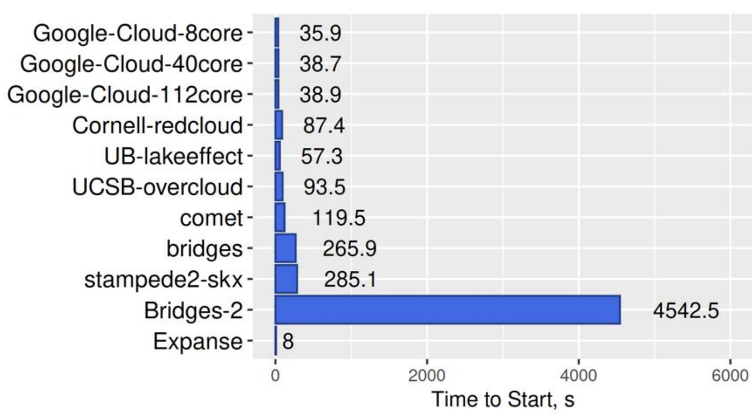

Figure 5. Time to get access to computing resources.

Another important aspect is the waiting time till resource is available for computation. On the Cloud platforms, it was measured as a time from the instance creation request till the first log-in to the system. On HPC resources, it was measured as time between batch job submission and resource allocation. It is important to note that in the Cloud computing resources are allocated indefinitely while on HPC resources for a specified time. Because app kernels jobs are very short and use only a single node for this test, their waiting time was short, especially on the new less occupied resource from SDSC (Expanse). Here, Google Cloud has a smaller spin-up time than our OpenStack instances and provides access to compute resources in less than a one-minute timeframe. This is significantly smaller than that on busy HPC resources like PSC-Bridges-2 and slightly longer than on underutilized resources.

In summary, Google Cloud offers a highly competitive alternative for single node computation to HPC. The performance and its variability are within the range of traditional platforms.