Public Cloud IaaS Performance Report

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Introduction

Cloud infrastructure services (IaaS) is the fastest growing segment of the public cloud services market. According to Gartner, IaaS revenues worldwide in 2017 were $30 billion and are expected to grow to $83.5 billion by 2021, at an average YoY growth of 29%.

Choosing a cloud service provider (CSP) should be a well-researched process that considers many factors including performance, pricing, how well they will support you, do they meet your corporate/industry compliance and security requirements, and so on.

When it comes to performance/price, cloud costs are very much a function of performance SLAs. Without carefully mapping your compute/storage needs to the appropriate resources, you will pay for capacity (bandwidth, RAM, CPU, disk IO, etc.) that you don't need, and those costs can mount quickly. So when doing your due diligence on CSPs, it's important to compare "apples to apples" in terms of performance/price.

This report summarizes benchmarks that were conducted by IOD Cloud Research Technologies on four CSPs: AWS, Azure, GCP, and **Tecorp Group**—a global CSP operating out of ten global data centers that has been providing high performance, enterprise-grade, highly flexible IaaS services for over a decade.

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Determining the Right Size for Cloud VMs

Even though container adoption is growing by the day in modern enterprises, they too still rely on virtual machines for their daily workloads.

From a corporate aspect, many internal enterprise applications, such as CRM / ERP systems, e-mail servers, or file services, cannot be easily containerized. Even if they could, large companies aren't rushing to change what has worked for them for more than a decade, providing them with both stability and required performance. Even in fast paced environments where new compute resources are being created and destroyed every couple of minutes, VMs remain the dominant choice, especially with today's ease of use and customization options that public cloud providers offer.

In your own on-premise environment, provisioning VMs is quite a different task than doing so in the cloud. You can go only as high as your server configuration allows you to, and companies tend to overprovision resources until they reach hardware limitations. But the situation in cloud is different, as you pay for every additional CPU core, extra GB of RAM, or IOPS for your storage needs. That's why you need to carefully assess which VMs to provision and how you pick your public cloud provider: not all of the offerings give you the optimal performance at the desired price point.

From a SaaS vendor or start-up perspective, cost-to-performance ratio is a key consideration when choosing a cloud provider. In order to maximize SaaS margins or get the most out of a startup's limited budget, you need a cloud platform that scales easily and has a flexible pricing model that takes into account both predictable baseline traffic as well as demand spikes. In the case of SaaS vendors, high availability, global geographic distribution, robust security and, in some sectors, regulatory compliance are also critical cloud provider requirements. In addition, it is important for these businesses to avoid vendor lock-in; the cloud provider should seamlessly support hybrid and multi-cloud architectures, and even colocation scenarios in which it hosts the customer's equipment and connects it to the cloud.

There are four main categories to keep in mind when you want to provision cloud VMs:

CPU: Besides selecting the number of cores for your VM, be sure to notice which processor type and family the public cloud provider uses in their hypervisor. Also, familiarize yourself with the workload the specific VM will carry: is it an intensive CPU-aware application? Or does the application rely on some other category, for example, network or storage? For legacy apps, be sure it can support multi-core environments.

RAM: Expanding RAM can be quite expensive in the public cloud, so be sure to test your application locally and see how much RAM it requires. Sometimes, if the application will be used behind a load balancer, it's better to scale the application horizontally than to add more RAM to the VM. If your application is RAM-intensive, it won't hurt to check the RAM read and write speeds, for better throughput.

Storage: Second to CPU, the most important category when provisioning cloud VMs is storage. Providers usually offer you the option of choosing the size of the volume and the IOPS capacity. However, both can be bottlenecks for your application if not planned properly. Be sure to research the storage prices of all public providers before you decide to provision your VMs because you may end up having to pay a fortune if you want a volume with 10k IOPS or more.

Networking: Cloud providers usually offer 1 or 10 Gbps network interfaces for your VMs, along with the option of using static IP addresses (both internally and externally) and bridging interfaces if needed. If your VMs will be publicly reachable from the Internet, be sure to position them geographically in the region from where you expect most of the traffic to come. Don't neglect LAN bandwidth, especially if your VMs will communicate a lot among themselves.

Benchmarking Methodology

In order to carry out the benchmarking, an internal network with Internet access was provisioned through each cloud provider. Each network was comprised of 6 general-purpose VMs, ranging from 1 to 8 CPU cores and 1 to 32 GBs of RAM (see the detailed table below).

The VMs were only reachable via the Secure Shell (SSH) network protocol, for the purpose of running benchmark tests. All internal traffic among VMs was permitted because that was required for LAN speed tests.

The following tools were used for the various types of tests:

- **sysbench** for CPU performance
- **fio** and **hdparm** for disk bandwidth and read/write speed
- **dd** for RAM performance
- **ncmeter** for LAN speed and **ping** for packets per second (with one base VM per provider always available to host **ncmeter**)
- **speedtest** for WAN speed (download and upload)

All are open-source and free to use.

Sysbench stresses your CPU cores for a limited amount of time with a standard test of verifying prime numbers, which has proven to be accurate for determining CPU performance. This test is customized with the number of CPU cores and simultaneous threads sysbench will use and the maximum number sysbench will verify if it's a prime number.

Fio and **hdparm** are used to calculate read/write speeds and the total number of IOPS per volume, while system **dd** command is used to measure RAM-disk read and write speeds. (dd is present on all Linux distributions, and can be used for both cloning, but also wiping volumes, so be careful with it.)

Another system command useful for benchmarking local network performance is the well-known **ping**, while **ncmeter** will give you the actual speed of your local network compared to 1 Gbps or 10 Gbps per interface promised by your public provider. **Speedtest,** used in this benchmark comparison, is a command-line version of a popular test from the **www.speedtest.net** website.

For the purpose of our benchmark, we divided the most popular VMs from cloud providers into six categories (**Micro, Small, Medium, Large, XL and XXL**) and for each, we picked the most popular general-purpose VMs from all four tested public cloud providers. These six categories should fit most enterprise workloads, from very light applications or test/dev environments (suitable for **Micro** and **Small** VMs) up to intensive production or internal applications (databases, CRM/ERP, customer-oriented apps) that require highest availability and top-notch performance.

The following table describes the VMs that were provisioned, with every attempt being made to adapt the parameters for each VM so that the comparisons among the providers would be as close to “apples to apples” as possible:

Category	CSP	VM Type	CPU Model (all Intel® Xeon®)	Cores	RAM (GB)
Micro	AWS	t2.micro	CPU E5-2676 v3 @ 2.40GHz	1	1
	AZ	az.B1s	CPU E5-2673 v3 @ 2.40GHz	1	1
	GCP	gcp.MicroVM	CPU @ 2.20GHz	1	1
	TECORP GROUP	kt.1p1g	Gold 6150 CPU @ 2.70GHz	1	1
Small	AWS	t2.small	CPU E5-2676 v3 @ 2.40GHz	1	2
	AZ	az.B1ms	CPU E5-2673 v4 @ 2.30GHz	1	2
	GCP	gcp.SmallVM	CPU @ 2.20GHz	1	2
	TECORP GROUP	kt.1p2g	Gold 6150 CPU @ 2.70GHz	1	2
Medium	AWS	m5.large	Platinum 8175M CPU @ 2.50GHz	2	8
	AZ	az.F2s	CPU E5-2673 v4 @ 2.30GHz	2	4
	GCP	gcp.MediumVM	CPU @ 2.20GHz	2	4
	TECORP GROUP	kt.2p4g	Gold 6150 CPU @ 2.70GHz	2	4
Large	AWS	**There is no equivalent AWS general-purpose VM in this category**			
	AZ	az.F4s	CPU E5-2673 v4 @ 2.30GHz	4	8
	GCP	gcp.LargeVM	CPU @ 2.20GHz	4	8

	TECORP GROUP	kt.4p8g	Gold 6150 CPU @ 2.70GHz	4	8
XL	AWS	m5.xlarge	Platinum 8175M CPU @ 2.50GHz	4	16
	AZ	az.D4s_v3	CPU E5-2673 v4 @ 2.30GHz	4	16
	GCP	gcp.XLargeVM	CPU @ 2.20GHz	4	16
	TECORP GROUP	kt.4p16g	Gold 6150 CPU @ 2.70GHz	4	16
XXL	AWS	m5.2xlarge	Platinum 8175M CPU @ 2.50GHz	8	32
	AZ	az.F8s	CPU E5-2673 v4 @ 2.30GHz	8	16
	GCP	gcp.XXLargeVM	CPU @ 2.20GHz	8	16
	TECORP GROUP	kt.8p16g	Gold 6150 CPU @ 2.70GHz	8	16

The benchmarking script, available at https://github.com/cloudwm/cloudbenchmark, was run on each VM separately, with the output results written directly to the VM. Each script command had three arguments: the VM type, which also determined the name of the output CSV file into which the results were written; the IP address of the **ncmeter** receiver for the LAN test; and the block device being used ("xvd", "sd", or "nvme"). The CLIs for the tests that were run are included with the benchmarking results themselves.

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Benchmarking Results

CPU BENCHMARK

Using **sysbench**, CPU speed (in seconds) was tested with three different core settings (single, maximum and double) and two concurrent thread loads (10K and 20K) per configuration, i.e., six times per VM:

Single core (1Core)	10K threads	20K threads
Maximum number of cores (MaxCore)	10K threads	20K threads
Double the number of cores (DblCore)	10K threads	20K threads

CPU BENCHMARK COMMAND-LINE

```
CORES=$(cat /proc/cpuinfo | grep processor | wc -l)
```

- `# 1Core-10k sysbench --test=cpu --num-threads=1 --cpu-max-prime=10000 run >>/tmp/results/out.cpu1-10k 2>&1`

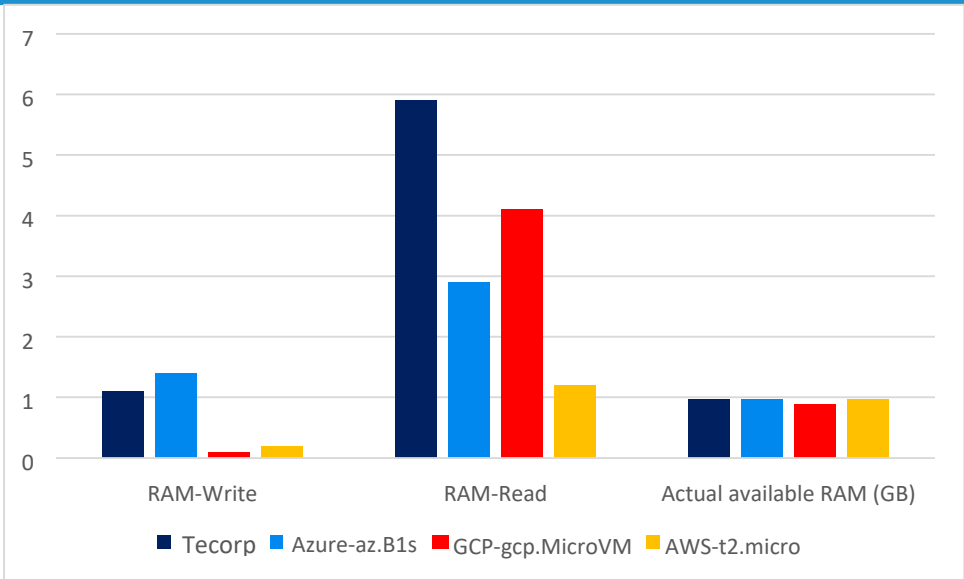
- `# MaxCore-10k`
- `sysbench --test=cpu --num-threads=$CORES --cpu-max-prime=10000 run >>/tmp/results/out.cpuMax-10k 2>&1`

- `# DblCore-10k`
- `sysbench --test=cpu --num-threads=$(($CORES*2)) --cpu-max-prime=10000 run >>/tmp/results/out.cpuDouble-10k 2>&1`

- `# 1Core-20k`
- `sysbench --test=cpu --num-threads=1 --cpu-max-prime=20000 run >>/tmp/results/out.cpu1-20k 2>&1`
- `# MaxCore-20k`
- `sysbench --test=cpu --num-threads=$CORES --cpu-max-prime=20000 run >>/tmp/results/out.cpuMax-20k 2>&1`

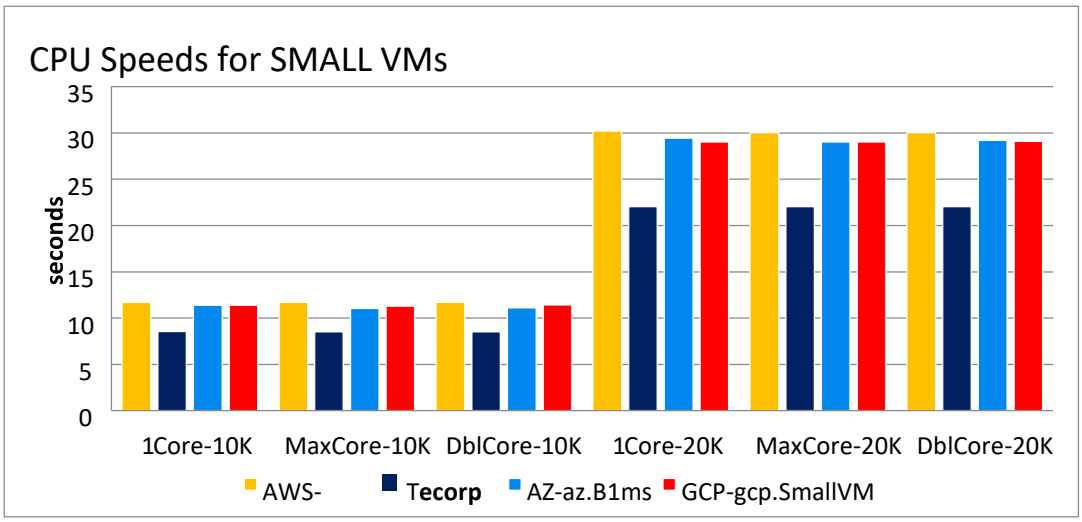
- `# DblCore-20k`
- `sysbench --test=cpu --num-threads=$(($CORES*2)) --cpu-max-prime=20000 run >>/tmp/results/out.cpuDouble-20k 2>&1`

CPU BENCHMARK RESULTS: MICRO VM



	Tecorp Group	AZ-az.B1s	GCP-gcp.MicroVM	AWS-t2.micro
RAM-Write	1.1	1.4	0.0873	0.182
RAM-Read	5.9	2.9	4.1	1.2
Actual available RAM (GB)	0.967541	0.969048	0.878426	0.962578

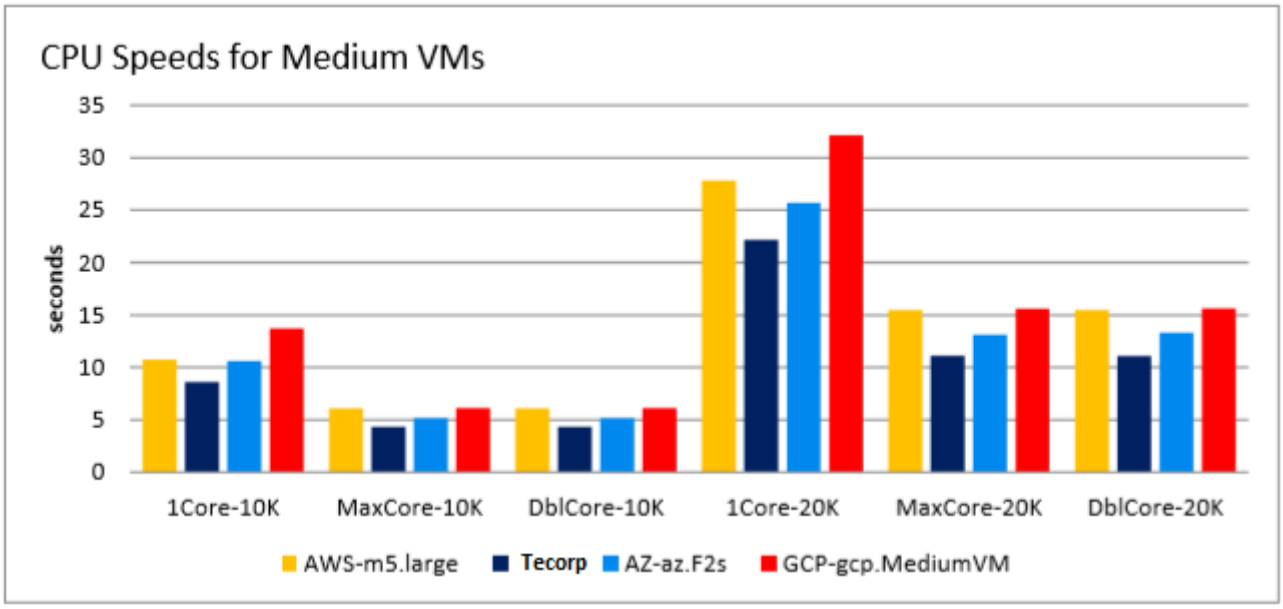
CPU BENCHMARK RESULTS: SMALL VM



Note: The smaller the result, the better the CPU speed performance.

	AWS-t2.small	Tecorp Group	AZ-az.B1ms	GCP-gcp.SmallVM
1Core-10K	11.6847	8.5387	11.3769	11.3721
MaxCore-10K	11.6817	8.5341	11.0362	11.2887
DblCore-10K	11.6978	8.5346	11.1063	11.4414
1Core-20K	30.209	22.0309	29.4407	29.0513
MaxCore-20K	30.0297	22.024	29.0036	29.0066
DblCore-20K	30.0051	22.0383	29.194	29.09

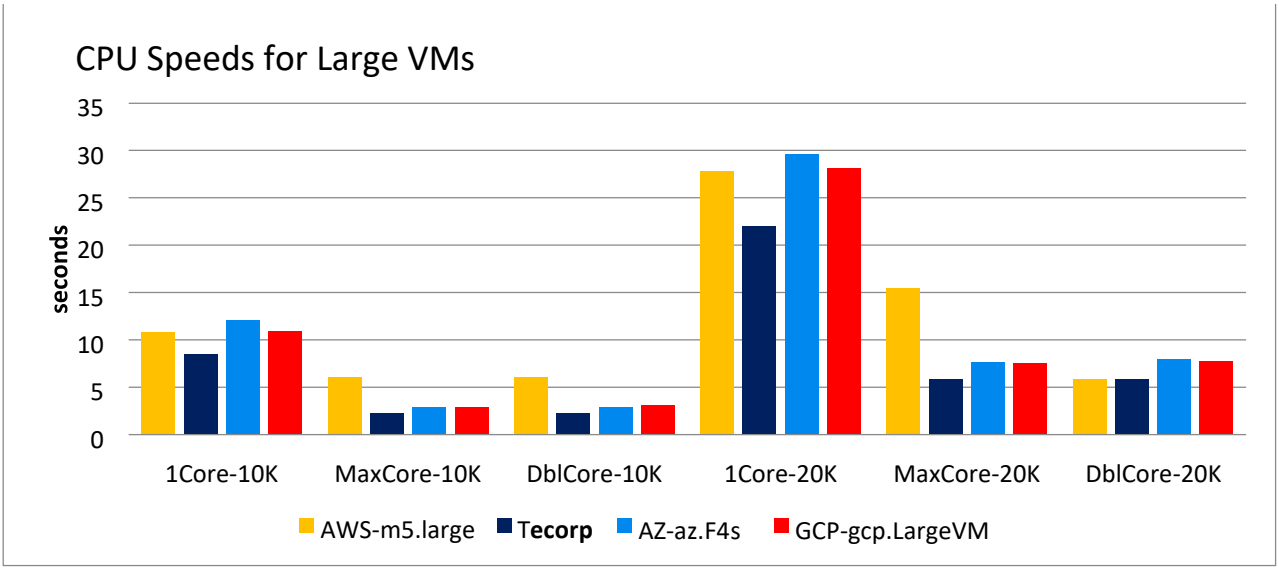
CPU BENCHMARK RESULTS: MEDIUM VM



Note: The smaller the result, the better the CPU speed performance.

	AWS-m5.large	Tecorp Group	AZ-az.F2s	GCP-gcp.MediumVM
1Core-10K	10.7547	8.5966	10.6115	13.6937
MaxCore-10K	6.1043	4.31	5.1818	6.1291
DblCore-10K	6.0942	4.311	5.1751	6.1233
1Core-20K	27.8143	22.1739	25.6734	32.129
MaxCore-20K	15.4872	11.1065	13.111	15.5965
DblCore-20K	15.4821	11.0862	13.3114	15.625

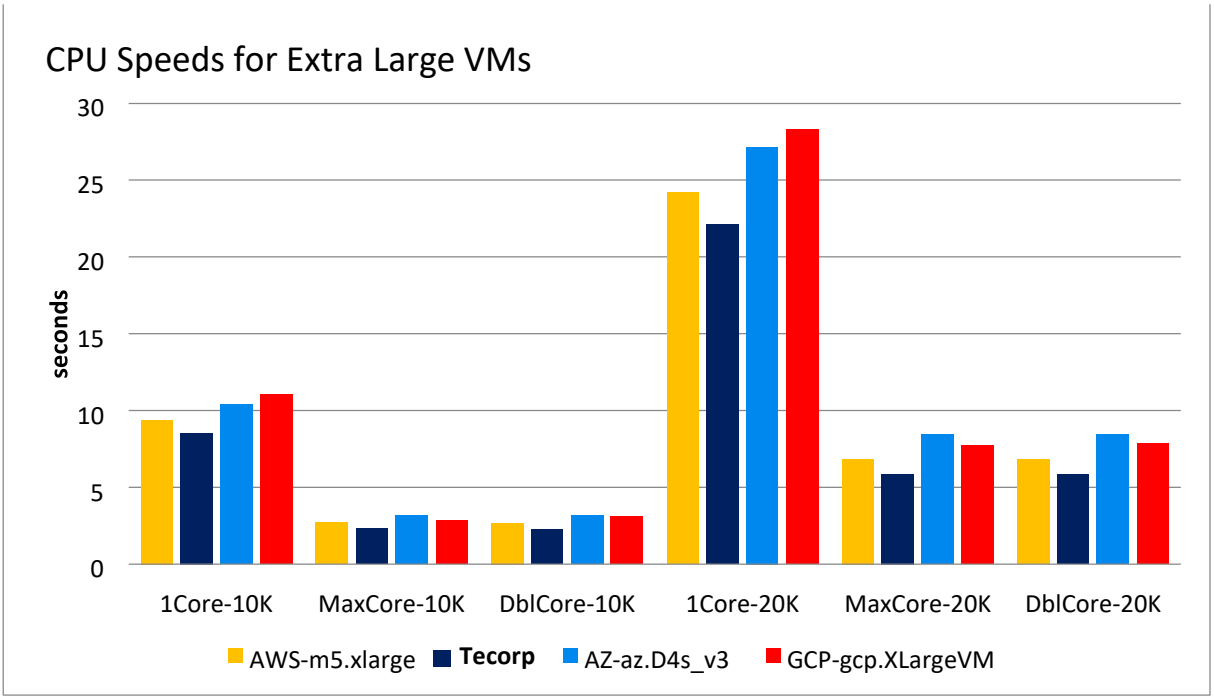
CPU BENCHMARK RESULTS: LARGE VM



Note: The smaller the result, the better the CPU speed performance.

	AWS-m5.large	Tecorp Group	AZ-az.F4s	GCP-gcp.LargeVM
1Core-10K	10.7547	8.5269	12.0556	10.9347
MaxCore-10K	6.1043	2.2705	2.8962	2.8898
DblCore-10K	6.0942	2.2746	2.8951	3.0538
1Core-20K	27.8143	22.0369	29.6443	28.115
MaxCore-20K	15.4872	5.8499	7.5768	7.5677
DblCore-20K	5.8254	5.825	7.9221	7.765

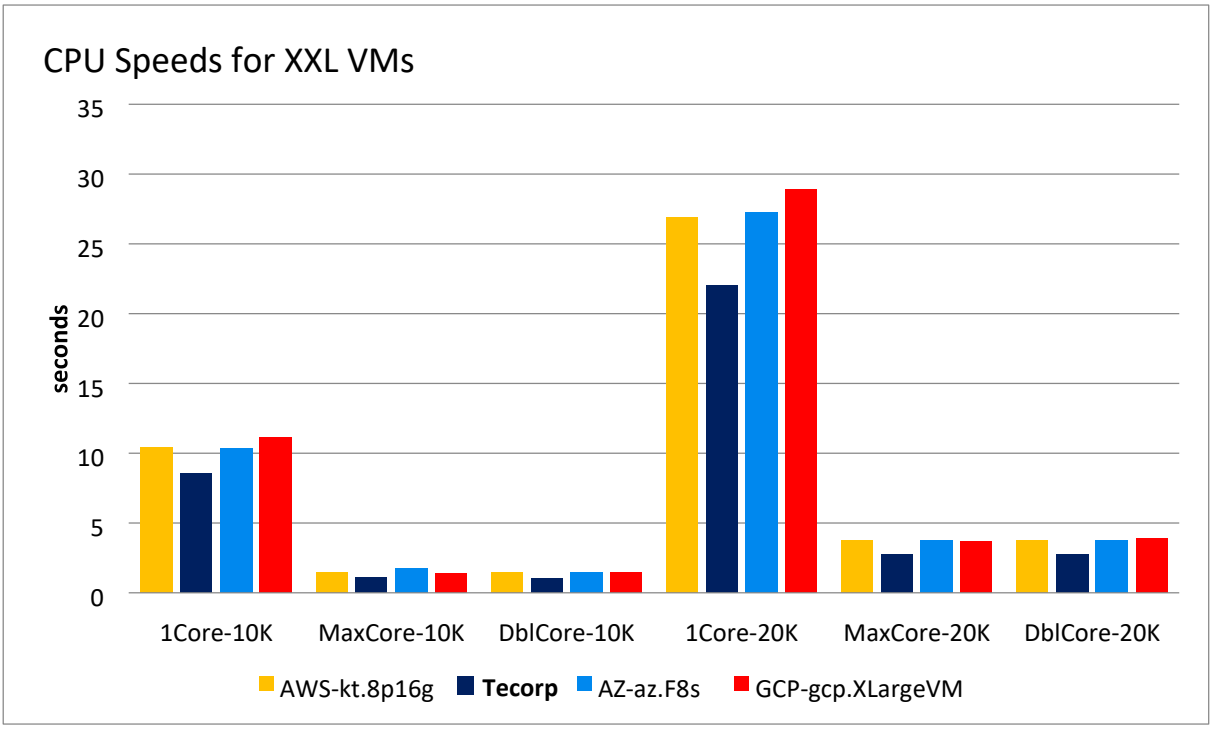
CPU BENCHMARK RESULTS: XL VM



Note: The smaller the result, the better the CPU speed performance.

	AWS-m5.xlarge	Tecorp Group	AZ-az.D4s_v3	GCP-gcp.XLargeVM
1Core-10K	9.378	8.5428	10.3825	11.0567
MaxCore-10K	2.7081	2.2988	3.131	2.8383
DblCore-10K	2.6854	2.2683	3.1702	3.0762
1Core-20K	24.1955	22.1253	27.1566	28.2983
MaxCore-20K	6.8462	5.8733	8.454	7.7078
DblCore-20K	6.814	5.8254	8.4067	7.8204

CPU BENCHMARK RESULTS: XXL VM



Note: The smaller the result, the better the CPU speed performance.

	AWS-kt.8p16g	Tecorp Group	AZ-az.F8s	GCP-gcp.XLargeVM
1Core-10K	10.4386	8.5301	10.3723	11.1414
MaxCore-10K	1.5009	1.079	1.7636	1.3936
DblCore-10K	1.4789	1.0702	1.4468	1.4851
1Core-20K	26.8972	22.0086	27.2476	28.9378
MaxCore-20K	3.7907	2.7637	3.7478	3.7076
DblCore-20K	3.7639	2.7567	3.7351	3.8797

CPU BENCHMARK CONCLUSIONS

Tecorp Group's CPUs brings clear benefits in terms of CPU speed:

- In all configurations, Tecorp Group's CPU results were the lowest, i.e., the best performance.
- The lower Tecorp Group CPU results were particularly noticeable in the smaller VMs (micro and small) under the heavier thread load (20K), providing a very advantageous performance/cost ratio.

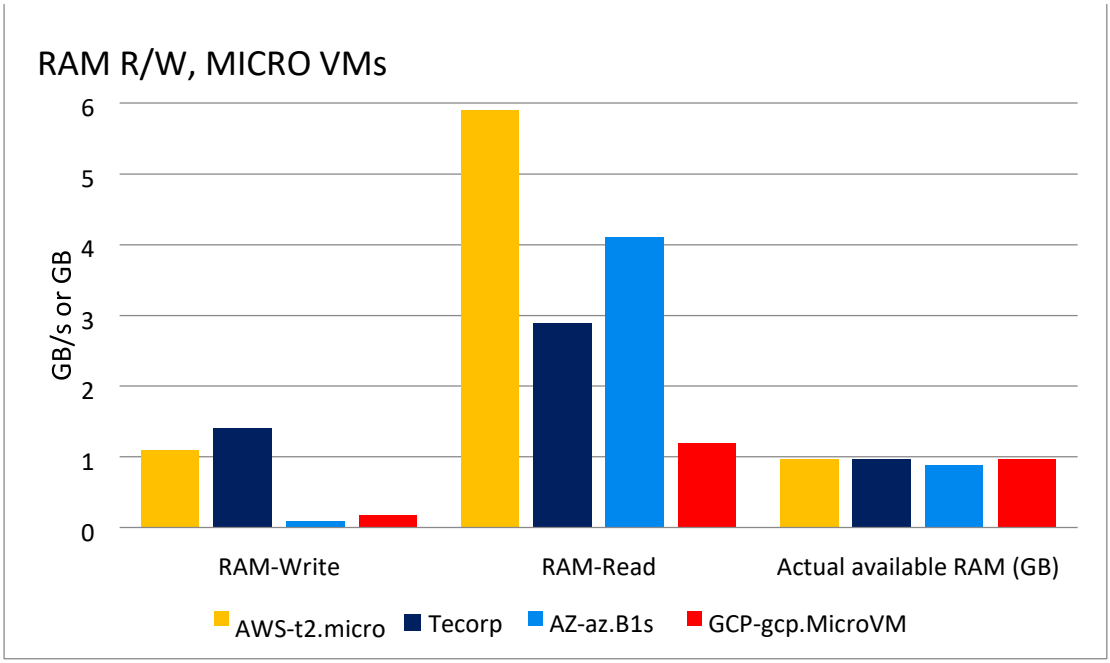
RAM BENCHMARK

VM memory speed has an important impact on latency. The higher the transfer rate, the better the performance. Using the **dd** test, RAM transfer speed (in GB/sec) was measured during read and write operations for each VM category (micro, small, medium, large, XL and XXL). In the charts below, the actual memory (in GBs) available to the VM during the test is also noted. For each operation the `blocksize` was defined as 1MiB and the number of blocks to be read or written (`count`) was limited to 512.

RAM BENCHMARK COMMAND-LINE

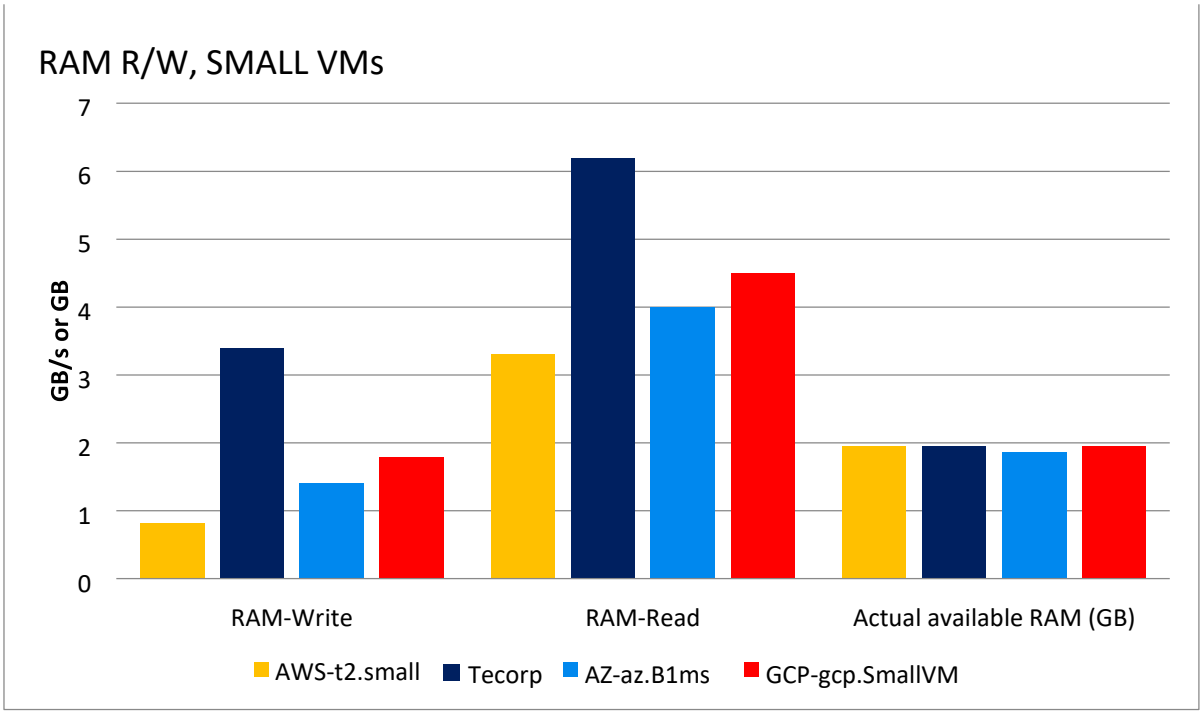
```
# RAM-Write (GB/s):

dd if=/dev/zero of=/tmp/TEST_RAM/data_tmp bs=1M count=512 >>
/tmp/results/out.mem-write 2>&1



# RAM-Read (GB/s):

dd if=/tmp/TEST_RAM/data_tmp of=/dev/null bs=1M count=512 >>
/tmp/results/out.mem-read 2>&1
```

RAM BENCHMARK RESULTS: MICRO VM



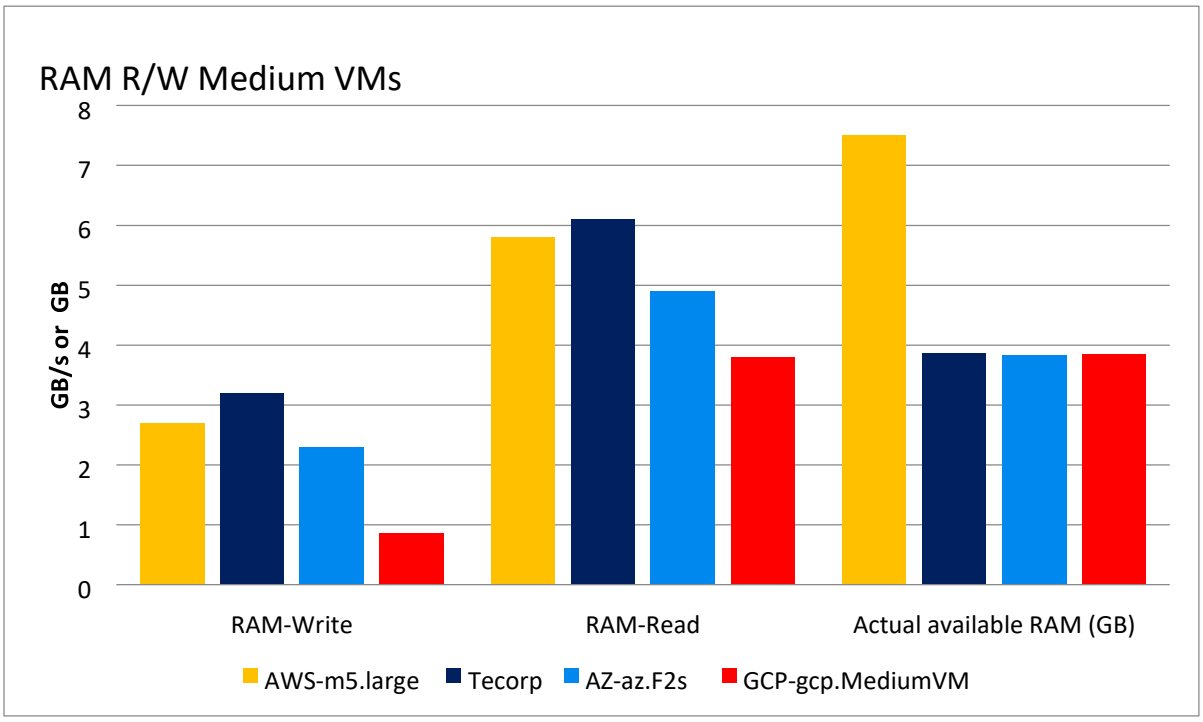
	AWS-t2.micro	Tecorp Group	AZ-az.B1s	GCP-gcp.MicroVM
RAM-Write	1.1	1.4	0.0873	0.182
RAM-Read	5.9	2.9	4.1	1.2
Actual available RAM (GB)	0.967541	0.969048	0.878426	0.962578

RAM BENCHMARK RESULTS: SMALL VM



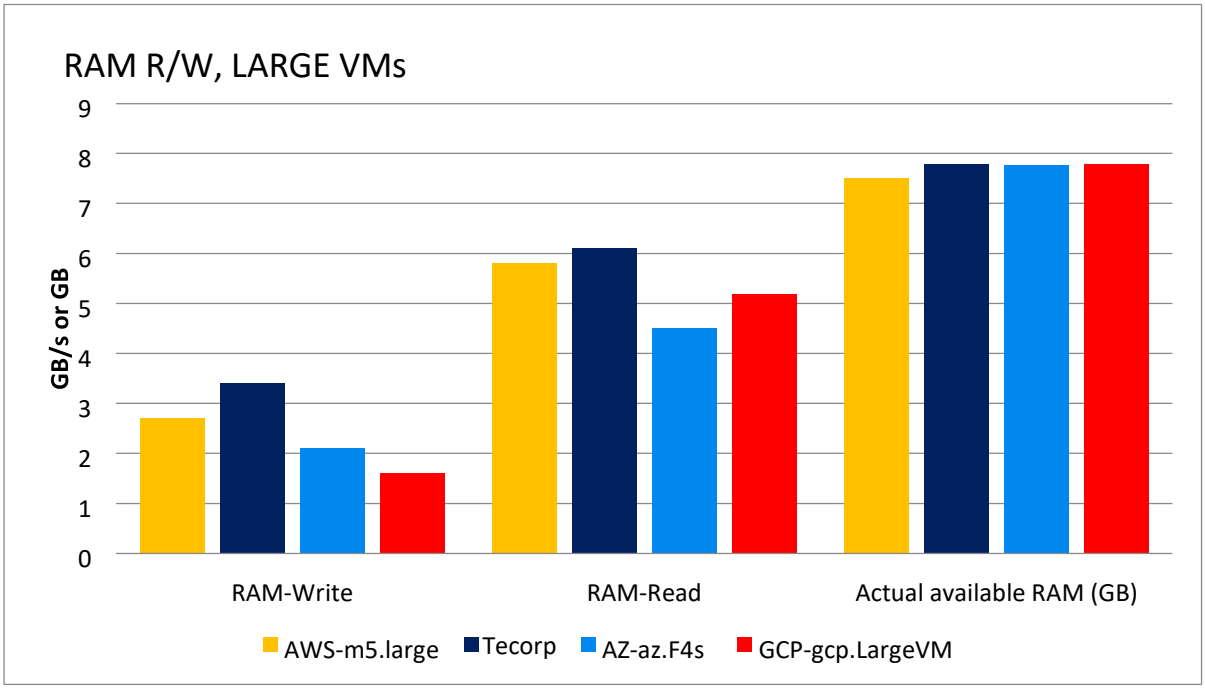
	AWS-t2.small	Tecorp Group	AZ-az.B1ms	GCP-gcp.SmallVM
RAM-Write	0.818	3.4	1.4	1.8
RAM-Read	3.3	6.2	4	4.5
Actual available RAM (GB)	1.95192	1.95342	1.8628	1.94695

RAM BENCHMARK RESULTS: MEDIUM VM



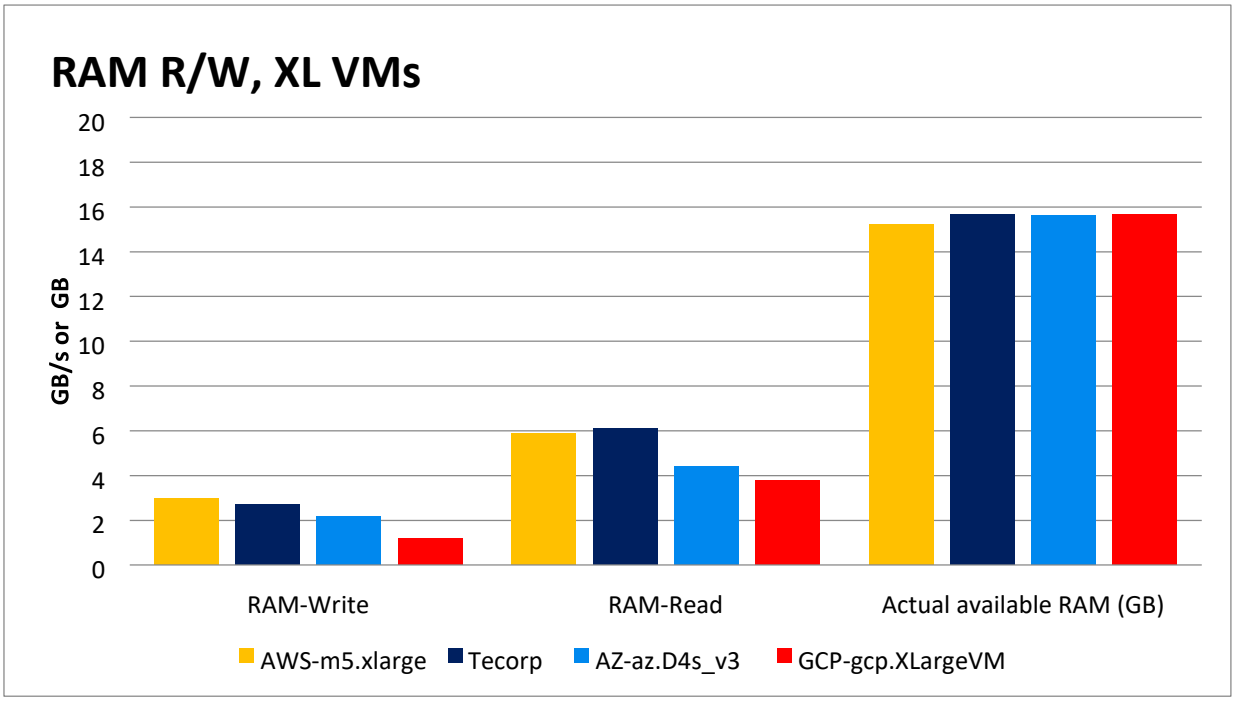
	AWS-m5.large	Tecorp Group	AZ-az.F2s	GCP-gcp.MediumVM
RAM-Write	2.7	3.2	2.3	0.868
RAM-Read	5.8	6.1	4.9	3.8
Actual available RAM (GB)	7.50777	3.85904	3.83158	3.85263

RAM BENCHMARK RESULTS: LARGE VM



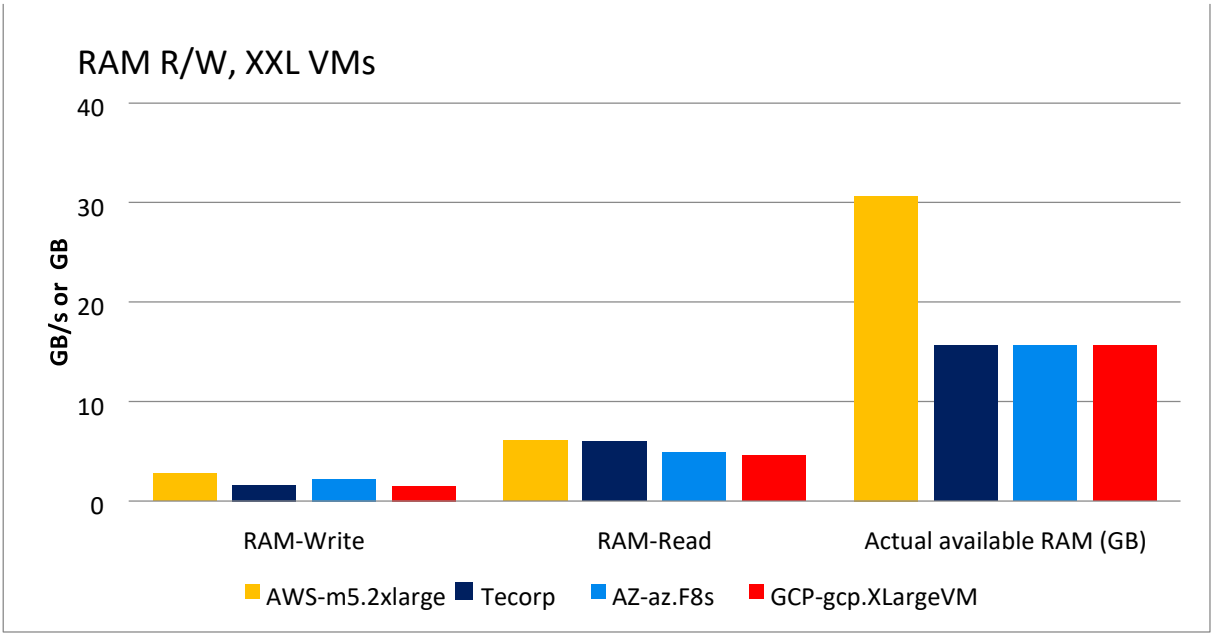
	AWS-m5.large	Tecorp Group	AZ-az.F4s	GCP-gcp.LargeVM
RAM-Write	2.7	3.4	2.1	1.6
RAM-Read	5.8	6.1	4.5	5.2
Actual available RAM (GB)	7.50777	7.79628	7.76908	7.78978

RAM BENCHMARK RESULTS: XL VM



	AWS-m5.xlarge	Tecorp Group	AZ-az.D4s_v3	GCP-gcp.XLargeVM
RAM-Write	3	2.7	2.2	1.2
RAM-Read	5.9	6.1	4.4	3.8
Actual available RAM (GB)	15.2185	15.6713	15.6441	15.6648

RAM BENCHMARK RESULTS: XXL VM



	AWS-m5.2xlarge	Tecorp Group	AZ-az.F8s	GCP-gcp.XLargeVM
RAM-Write	2.8	1.6	2.2	1.5
RAM-Read	6.1	6	4.9	4.6
Actual available RAM (GB)	30.6398	15.6707	15.6441	15.6641

RAM BENCHMARK CONCLUSIONS

- Tecorp Group's RAM read-write transfer speeds were significantly faster in the Small VM category, and equivalent to the other cloud service providers in all the other categories.
- The one exception to the above is the Read transfer speed in the Micro VM category. Given the consistency of the other results, this outlying result is probably due to a test artefact.
- Tecorp Group read-write memory speed is particularly notable in the Medium and XXL VM categories, this might be related to running VMware hypervisor where

DISK BENCHMARK

Using the **FIO** (Flexible I/O) random-write tester, disk performance was measured on six mounted volumes per VM: the base volume (50 GB) plus five additional volumes as follows:

Vol. #	AWS	Azure[1]	GCP	Tecorp Group[2]
1	100GB (300 IOPS)	64GB (300 IOPS)	10GB (300 IOPS)	100GB
2	100GB (1000 IOPS)	256GB (1000 IOPS)	34GB (1000 IOPS)	100GB
3	100GB (5000 IOPS)	1000GB (5000 IOPS)	167GB (5000 IOPS)	100GB
4	200GB (10000 IOPS)	2048GB (7500 IOPS)	334GB (10000 IOPS)	200GB
5	400GB (20000 IOPS)		500GB (15000 IOPS)	400GB

Disk performance was benchmarked according to the following parameters:

- IO bandwidth, in MB/sec
- R/W IO, in MB
- R/W BW, in KB/sec
- R/W IOPS

NOTE: The IO bandwidth and the IOPS read-write results shown in this section are for the base volume as well as the volume disks provisioned for 1K and 10K IOPS. These parameter and configuration benchmarks are fully representative of the results recorded for all of the tested disk parameters and configurations.

The maximum IOPS for Azure disks is 7500 IOPS, so the Azure disk tests were done for the base[1] volume plus the four volumes shown in the table.

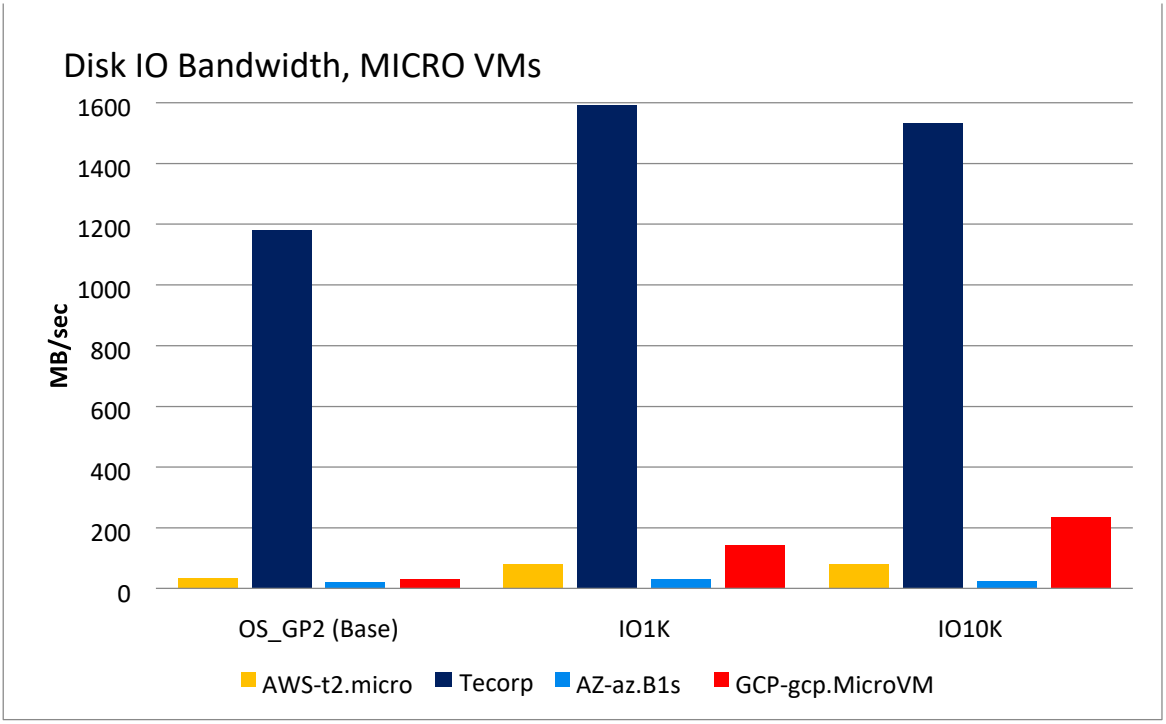
Tecorp Group provides unlimited IOPS per volume.[2]

DISK BENCHMARK COMMAND-LINE

```
fio --directory=/OS-GP2 --name fio_test_file --direct=1 --rw=randwrite --bs=4k --size=1G
--numjobs=16 --time_based --runtime=180 --group_reporting -norandommap >>
/tmp/results/out.disk-os-gp2-fio-write


fio --directory=/OS-GP2 --name fio_test_file  --direct=1 --rw=randread --bs=4k --size=1G
--numjobs=16 --time_based --runtime=180 --group_reporting -norandommap >>
/tmp/results/out.disk-os-gp2-fio-read


fio --directory=/IO300 --name fio_test_file --direct=1 --rw=randwrite --bs=4k -
-size=1G --numjobs=16 --time_based --runtime=180 --group_reporting -norandommap >>
/tmp/results/out.disk-io300-fio-write fio --directory=/IO300 --name fio_test_file  --
direct=1 --rw=randread --bs=4k -
-size=1G --numjobs=16 --time_based --runtime=180 --group_reporting -norandommap >>
/tmp/results/out.disk-io300-fio-read
 fio --directory=/IO1K --name fio_test_file --direct=1 --rw=randwrite --bs=4k -size=1G -
-numjobs=16 --time_based --runtime=180 --group_reporting --norandommap >>
/tmp/results/out.disk-io1k-fio-write


fio --directory=/IO1K --name fio_test_file  --direct=1 --rw=randread --bs=4k -size=1G --
numjobs=16 --time_based --runtime=180 --group_reporting --norandommap >>
/tmp/results/out.disk-io1k-fio-read


fio --directory=/IO5K --name fio_test_file --direct=1 --rw=randwrite --bs=4k -size=1G --
numjobs=16 --time_based --runtime=180 --group_reporting --norandommap >>
/tmp/results/out.disk-io5k-fio-write

fio --directory=/IO5K --name fio_test_file  --direct=1 --rw=randread --bs=4k -size=1G --
numjobs=16 --time_based --runtime=180 --group_reporting --norandommap >>
/tmp/results/out.disk-io5k-fio-read
 fio --directory=/IO10K --name fio_test_file --direct=1 --rw=randwrite --bs=4k -
-size=1G --numjobs=16 --time_based --runtime=180 --group_reporting -norandommap >>
/tmp/results/out.disk-io10k-fio-write


fio --directory=/IO10K --name fio_test_file  --direct=1 --rw=randread --bs=4k -
-size=1G --numjobs=16 --time_based --runtime=180 --group_reporting -norandommap >>
/tmp/results/out.disk-io10k-fio-read

fio --directory=/IO20K --name fio_test_file --direct=1 --rw=randwrite --bs=4k -
-size=1G --numjobs=16 --time_based --runtime=180 --group_reporting -norandommap >>
/tmp/results/out.disk-io20k-fio-write


fio --directory=/IO20K --name fio_test_file  --direct=1 --rw=randread --bs=4k -
-size=1G --numjobs=16 --time_based --runtime=180 --group_reporting -norandommap >>
/tmp/results/out.disk-io20k-fio-read
```

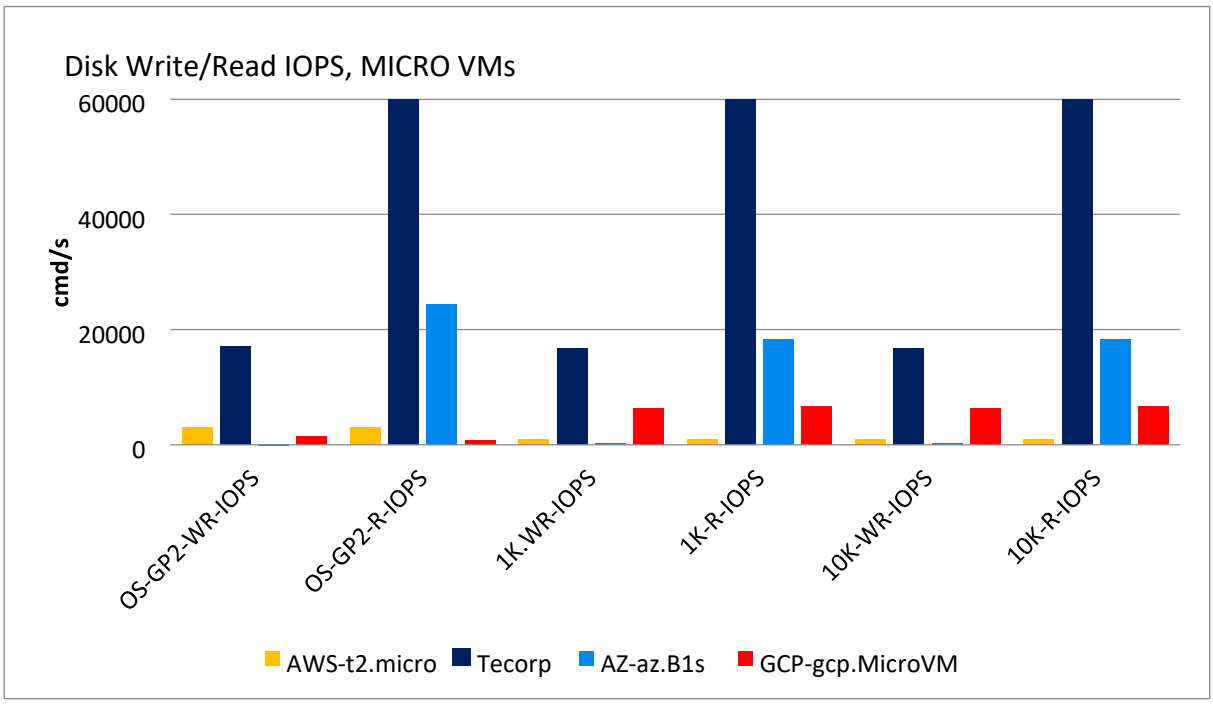
DISK BENCHMARK RESULTS: MICRO VMS

IO BANDWIDTH



	AWS-t2.micro	Tecorp Group	AZ-az.B1s	GCP-gcp.MicroVM
OS_GP2 (Base)	34.66	1181.1	4.92	32.09
IO1K	81.21	1592.24	8.44	142.31
IO10K	81.35	1533.29	7.47	235.28

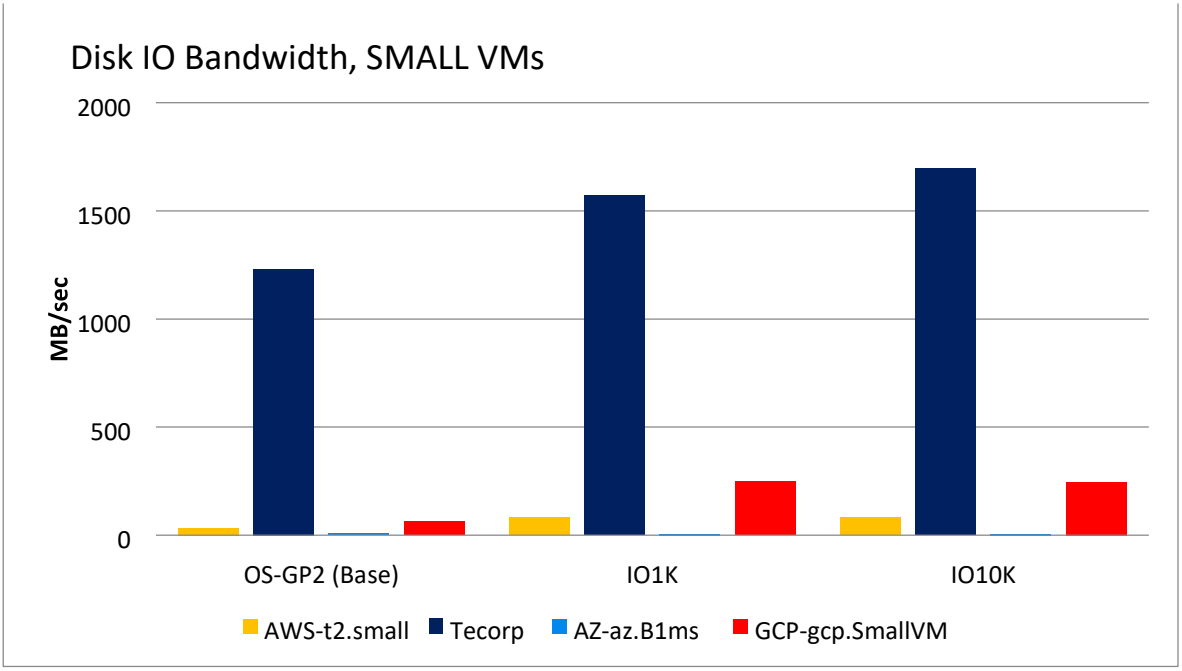
DISK WRITE/READ IOPS



	AWS-t2.micro	Tecorp Group	AZ-az.B1s	GCP-gcp.MicroVM
OS-GP2-WR-IOPS	3058	17205	193	1485
OS-GP2-R-IOPS	3052	62693	24385	749
1K.WR-IOPS	1022	16806	213	6283
1K-R-IOPS	1021	64819	18382	6680
10K-WR-IOPS	1022	16815	213	6283
10K-R-IOPS	1021	64857	18382	6680

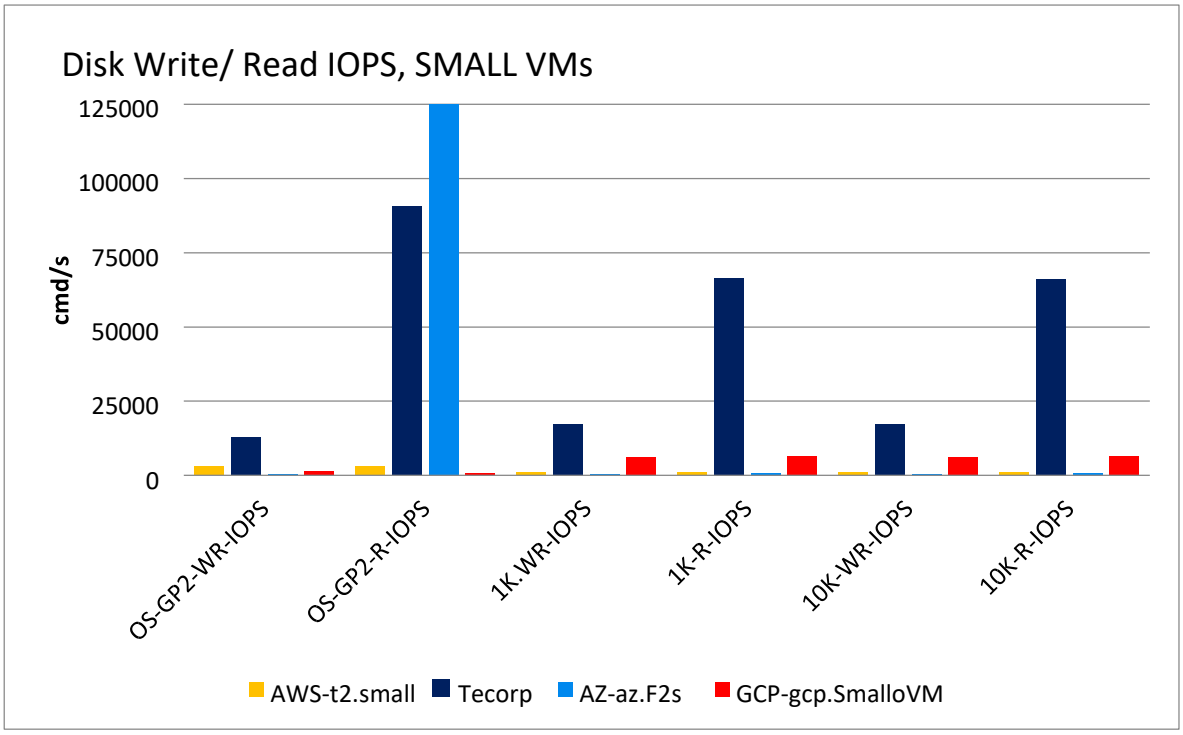
DISK PERFORMANCE RESULTS: SMALL VMS

IO BANDWIDTH



	AWS-t2.small	Tecorp Group	AZ-az.B1ms	GCP-gcp.SmallVM
OS-GP2 (Base)	34.777	1232.08	9.22	62.16
IO1K	81.25	1572.26	8.44	247.02
IO10K	81.37	1694.24	7.76	246.03

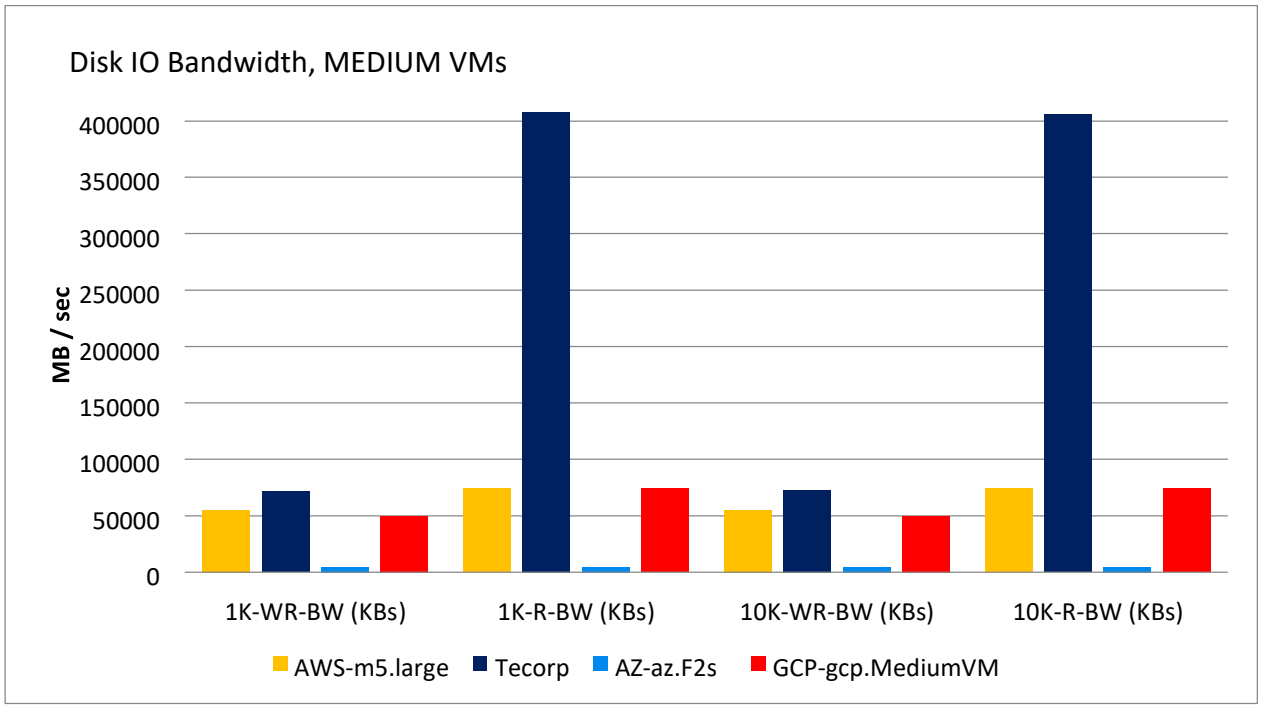
DISK WRITE/READ IOPS



	AWS-t2.small	Tecorp Group	AZ-az.F2s	GCP-gcp.SmalloVM
OS-GP2-WR-IOPS	3060	12753	520	1485
OS-GP2-R-IOPS	3051	90552	131000	749
1K.WR-IOPS	1022	17314	607	6295
1K-R-IOPS	1021	66533	789	6482
10K-WR-IOPS	1022	17173	607	6295
10K-R-IOPS	1021	66169	789	6482

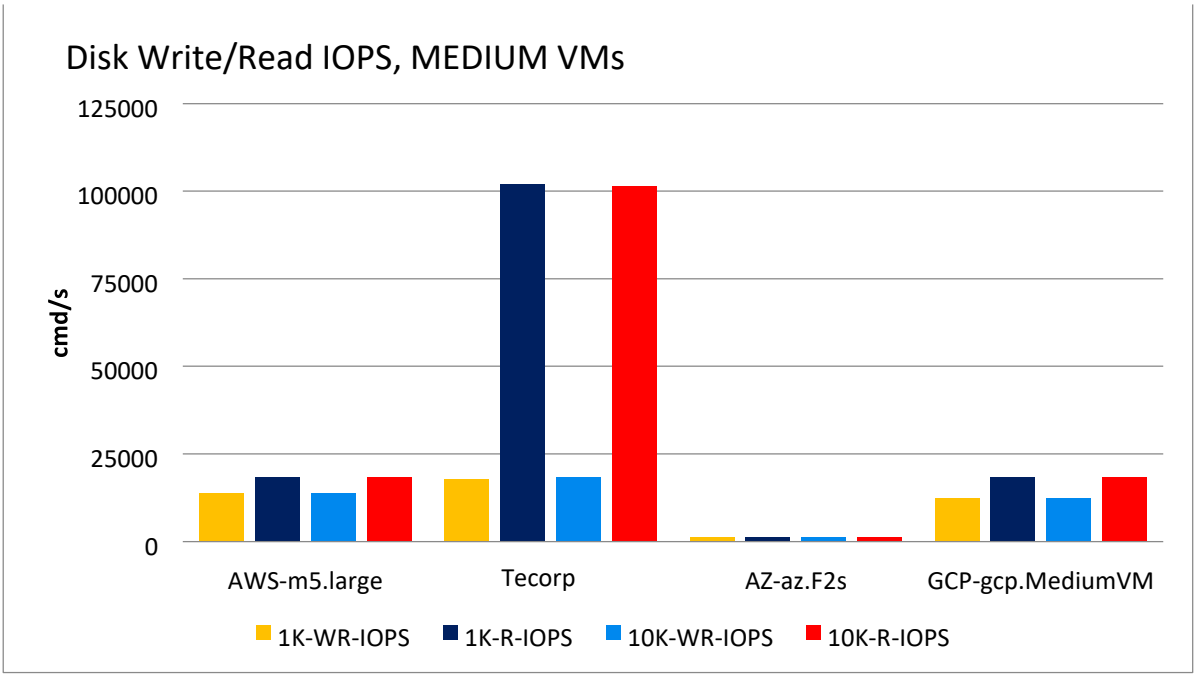
DISK PERFORMANCE RESULTS: MEDIUM VMS

IO BANDWIDTH



	AWS-m5.large	Tecorp Group	AZ-az.F2s	GCP-gcp.MediumVM
1K-WR-BW (KBs)	55314	71682	4474.9	49845
1K-R-BW (KBs)	74188	408026	4679.8	73857
10K-WR-BW (KBs)	55314	72928	4474.9	49845
10K-R-BW (KBs)	74188	405792	4679.8	73857

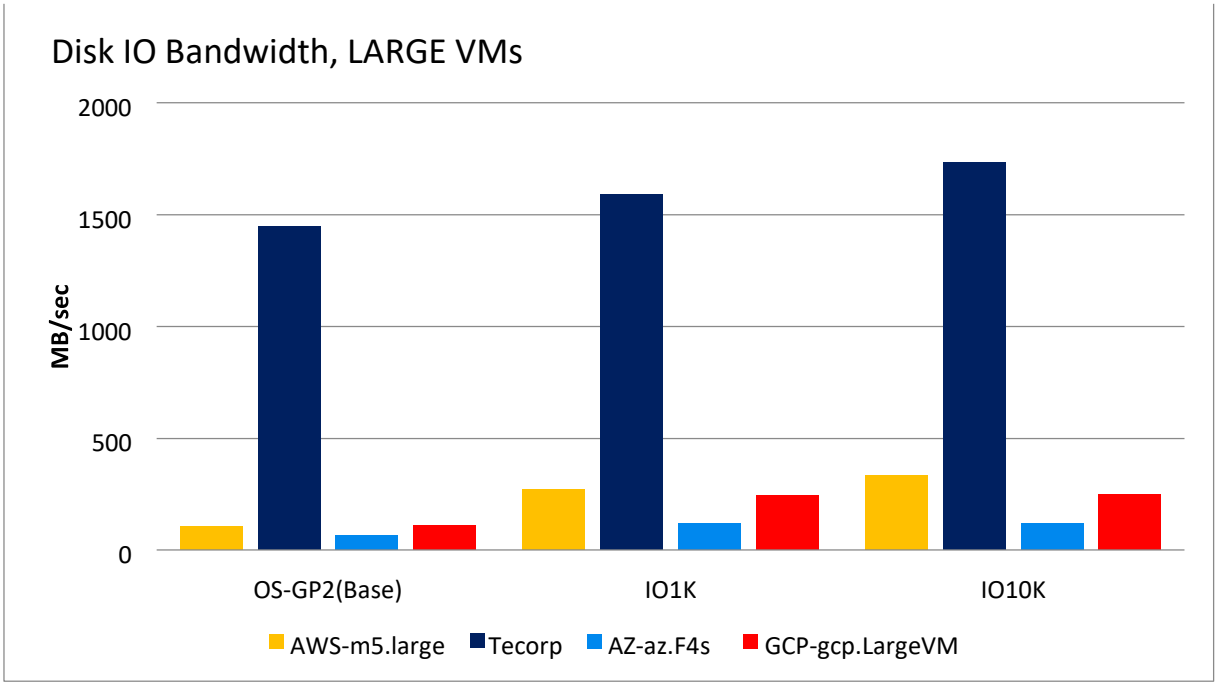
DISK WRITE/READ IOPS



	AWS-m5.large	Tecorp Group	AZ-az.F2s	GCPgcp.MediumVM
1K-WR-IOPS	13828	17920	1118	12461
1K-R-IOPS	18547	102006	1169	18464
10K-WR-IOPS	13828	18231	1118	12461
10K-R-IOPS	18547	101448	1169	18464

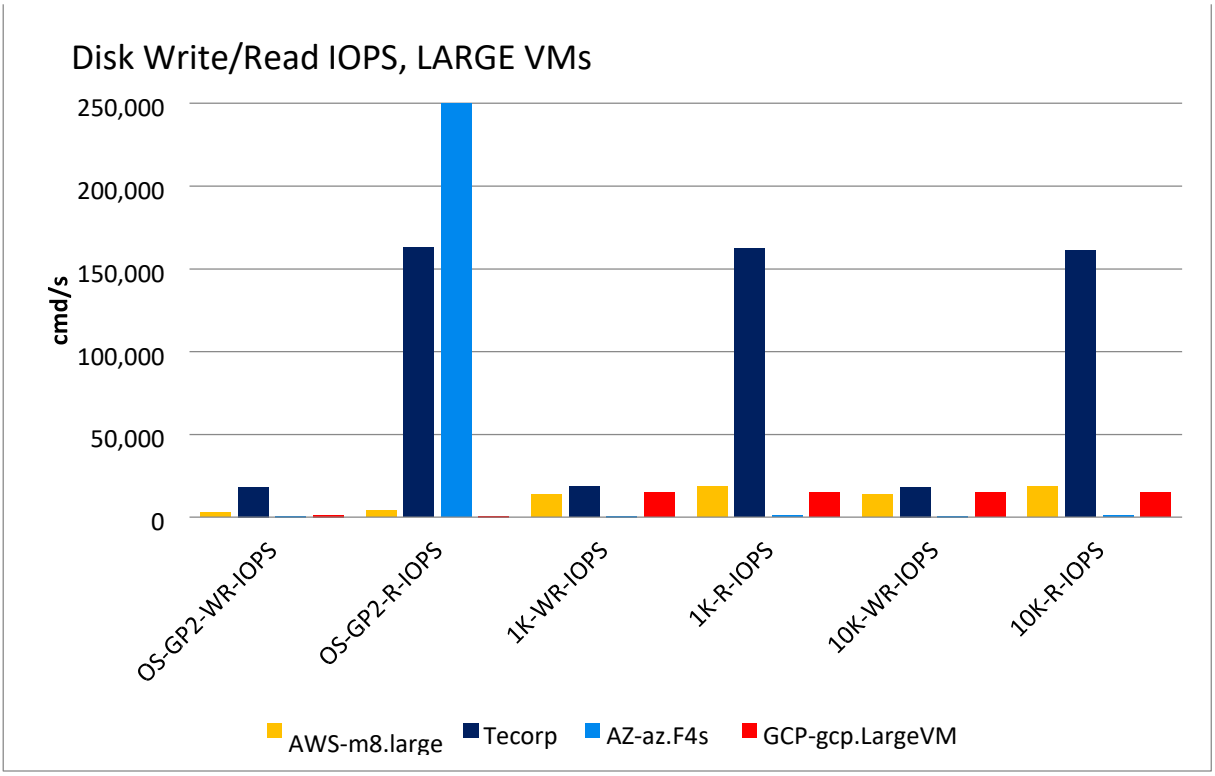
DISK PERFORMANCE RESULTS: LARGE VMS

IO BANDWIDTH



	AWS-m5.large	Tecorp Group	AZ-az.F4s	GCP-gcp.LargeVM
OS-GP2(Base)	105.03	1448.54	66.64	113.32
IO1K	272	1588.38	121.44	246.68
IO10K	334.97	1732.77	121.25	247.07

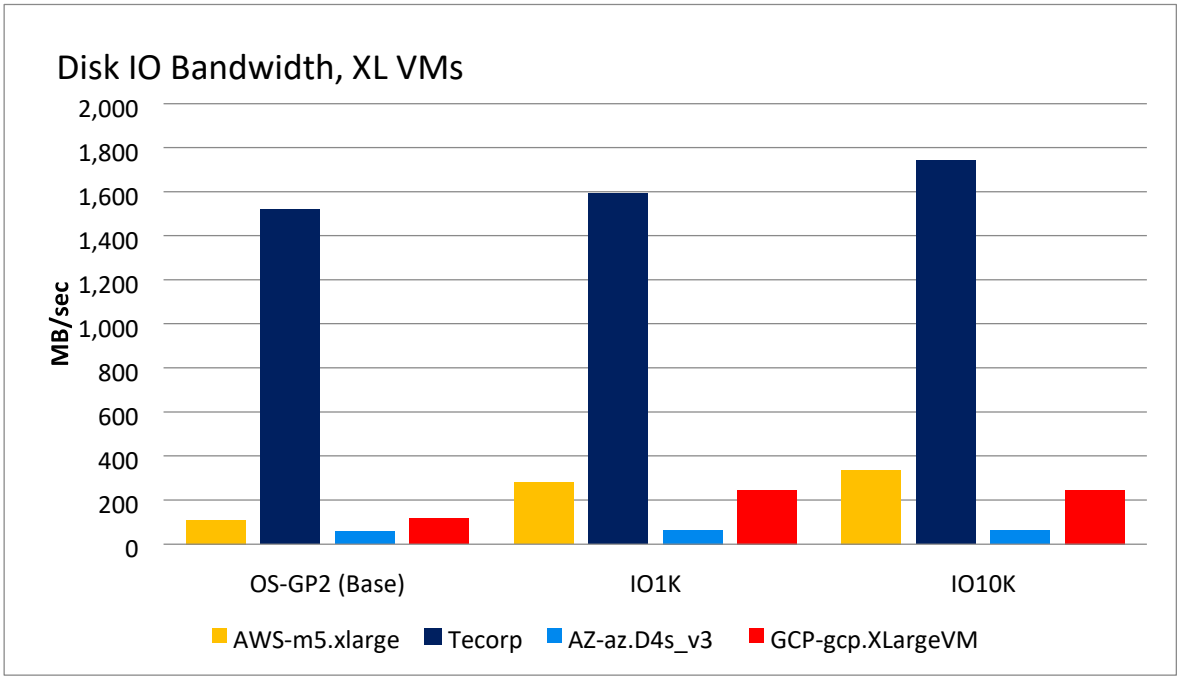
DISK WRITE/READ IOPS



	AWS-m8.large	Tecorp Group	AZ-az.F4s	GCP-gcp.LargeVM
OS-GP2-WR-IOPS	2,813	18,214	518	1,485
OS-GP2-R-IOPS	4,175	163,037	289,046	749
1K-WR-IOPS	13,828	18,368	1,114	14,865
1K-R-IOPS	18,547	162,238	1,238	15,217
10K-WR-IOPS	13,828	18,260	1,114	14,865
10K-R-IOPS	18,547	160,981	1,238	15,217

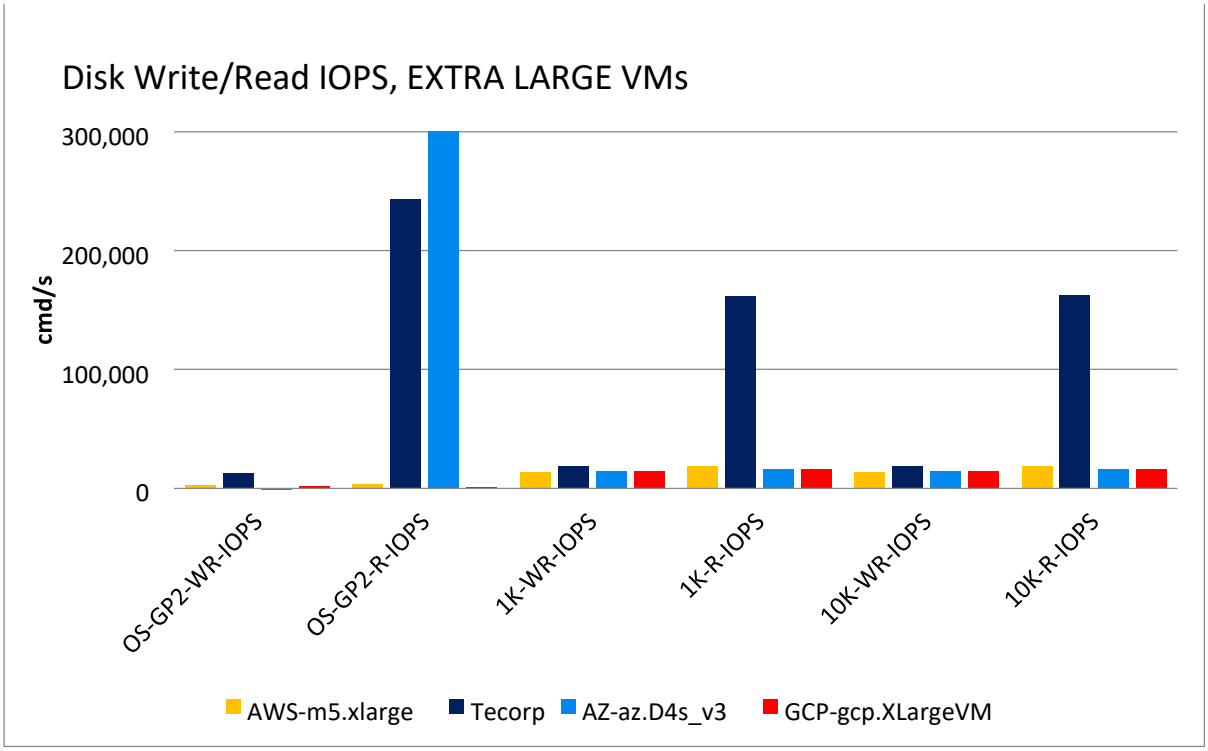
DISK PERFORMANCE RESULTS: EXTRA LARGE VMS

IO BANDWIDTH



	AWS-m5.xlarge	Tecorp Group	AZ-az.D4s_v3	GCP-gcp.XLargeVM
OS-GP2 (Base)	110	1,518	57.57	116
IO1K	278	1,592	64	245.44
IO10K	336	1,742	61	245

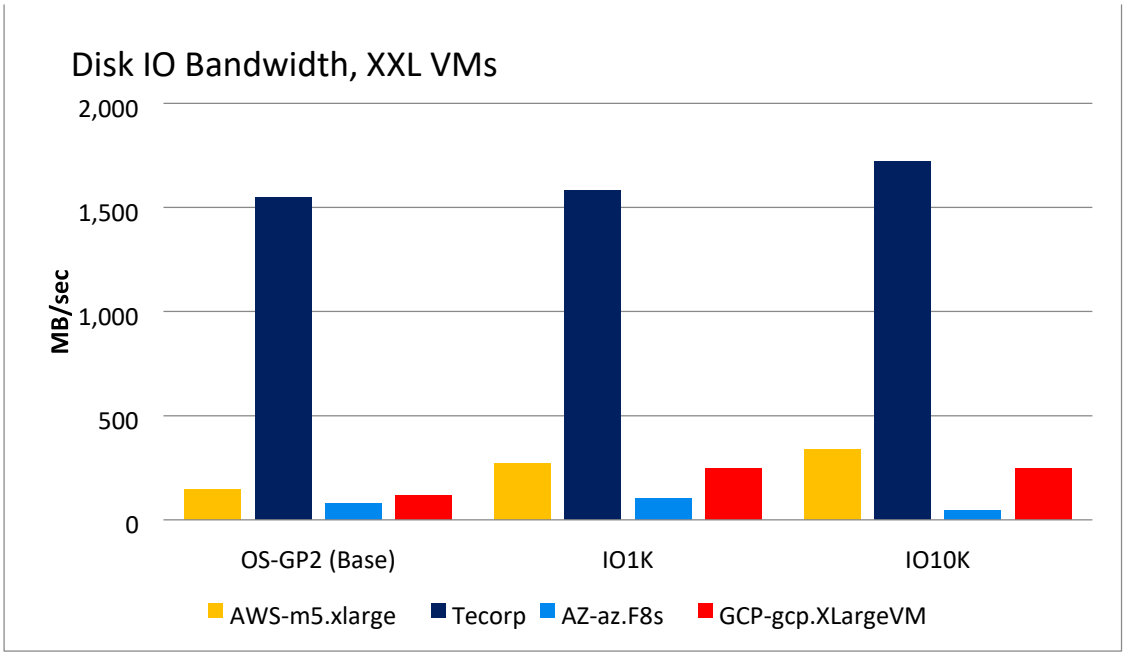
DISK WRITE/READ IOPS



	AWS-m5.xlarge	Tecorp Group	AZ-az.D4s_v3	GCP-gcp.XLargeVM
OS-GP2-WR-IOPS	2,826	13,185	363	1,485
OS-GP2-R-IOPS	3,975	242,908	310,758	749
1K-WR-IOPS	13,825	18,564	14,387	14,387
1K-R-IOPS	18,539	161,750	15878	15,878
10K-WR-IOPS	13,825	18,357	14,387	14387
10K-R-IOPS	18,539	162,260	15,878	15,878

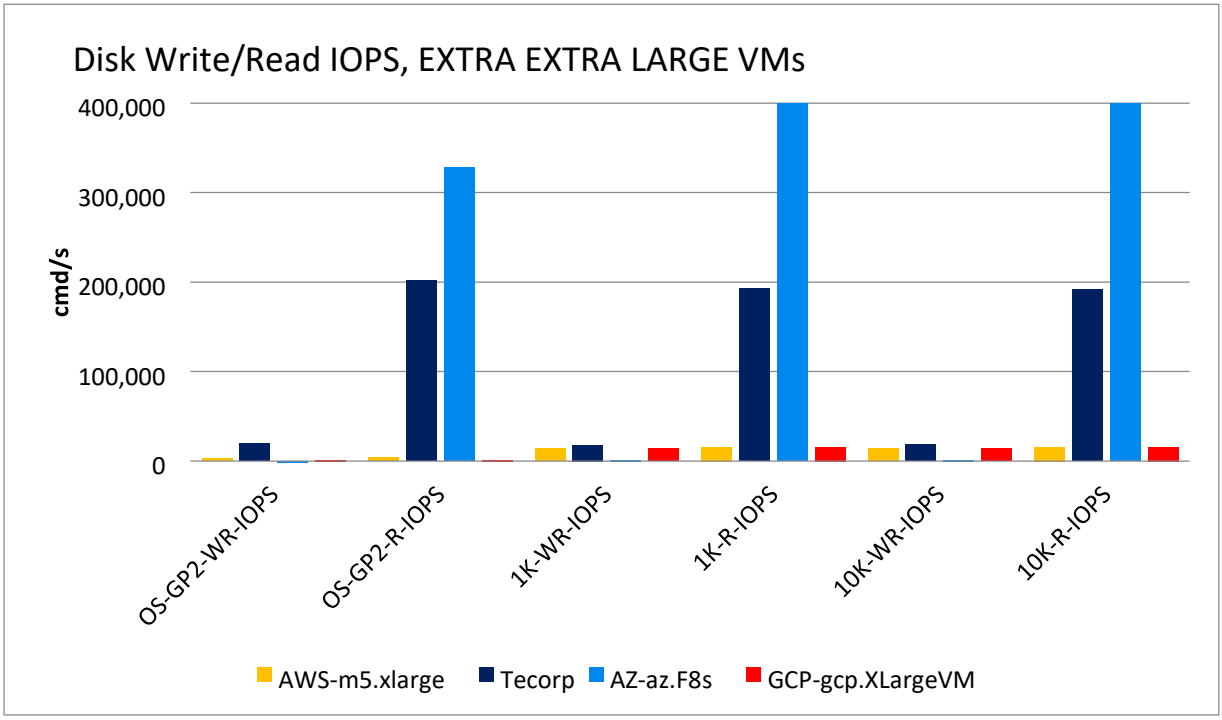
DISK PERFORMANCE RESULTS: EXTRA EXTRA LARGE VMS

IO BANDWIDTH



	AWS-m5.xlarge	Tecorp Group	AZ-az.F8s	GCP-gcp.XLargeVM
OS-GP2 (Base)	147	1,550	76.62	115
IO1K	271	1,581	103	245.83
IO10K	337	1,719	45	246

DISK WRITE/READ IOPS



	AWS-m5.xlarge	Tecorp Group	AZ-az.F8s	GCP-gcp.XLargeVM
OS-GP2-WR-IOPS	2,808	19,247	375	1,484
OS-GP2-R-IOPS	4,205	201,191	328,061	749
1K-WR-IOPS	14,149	17,928	1,109	14,149
1K-R-IOPS	15,703	192,880	592386	15,703
10K-WR-IOPS	14,149	18,108	1,109	14149
10K-R-IOPS	15,703	191,551	592,386	15,703

DISK BENCHMARK CONCLUSIONS

In contrast to the other CSPs that require the user to provision bandwidth and IOPS per volume, Tecorp Group places no limits on bandwidth or IOPS for its volumes. Thus all Tecorp Group users can achieve optimal latency and performance for their workloads at no extra cost:

IO bandwidth: For all VM categories, Tecorp Group's IO bandwidth is far superior (higher) than the other CSPs.

- Read IOPS: In general, Tecorp Group's IOPS rate during read operations was far higher than the other CSPs, with the exception of the XXL category, where AWS' IOPS rate was higher. In addition, it should be noted that AWS' IOPS read rate was generally higher than Tecorp Group's for the base volume.
- Write IOPS: Although Tecorp Group's IOPS rate during write operations was generally slower than for read operations, it out-performed all the other CSPs for all volume types and disk provisioning configurations.

NETWORK BENCHMARK

Network performance was assessed based on the following parameters:

- WAN Download and Upload speeds, in Mbits/second.
- LAN speed, Gbits/second
- Packet speed, in packets per second (pps)

WAN NETWORK BENCHMARK COMMAND-LINE

```
curl -s
https://raw.githubusercontent.com/sivel/speedtestcli/master/speedtest.py |
python - >> /tmp/results/out.speedtest 2>&1
```

LAN NETWORK BENCHMARK COMMAND-LINE

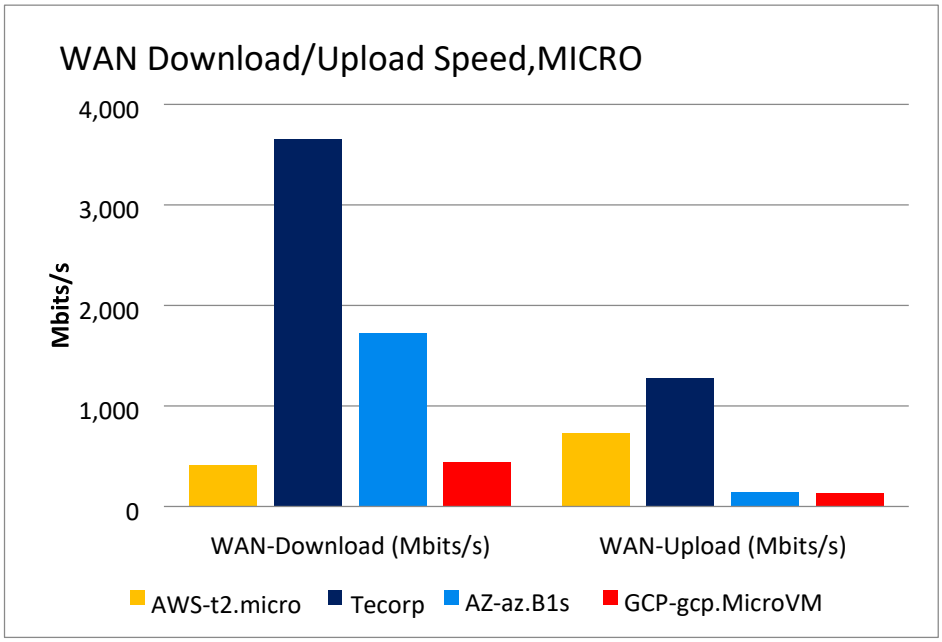
```
ncmeter $2 256M >> /tmp/results/out.lan 2>&1
```

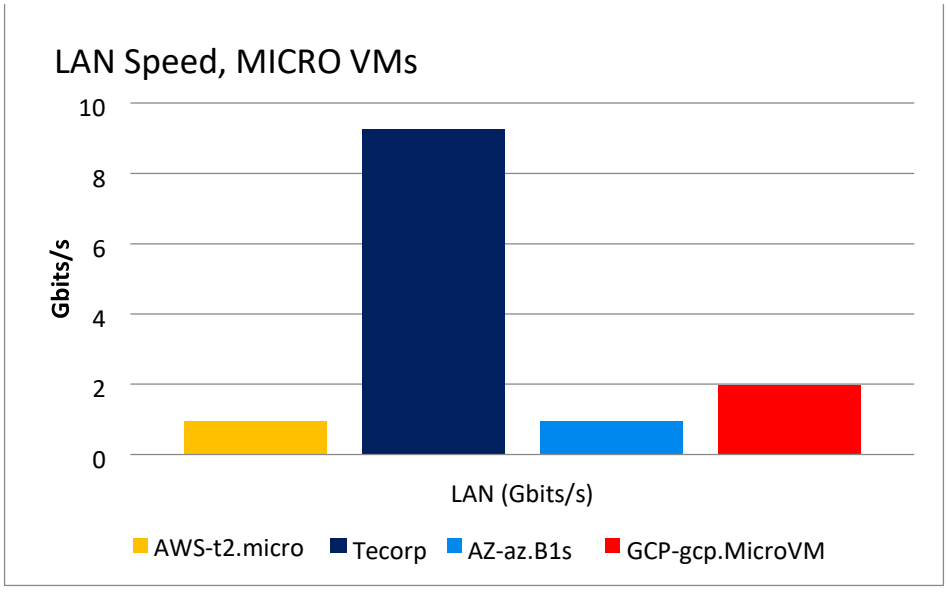
LAN NETWORK PPS BENCHMARK COMMAND-LINE

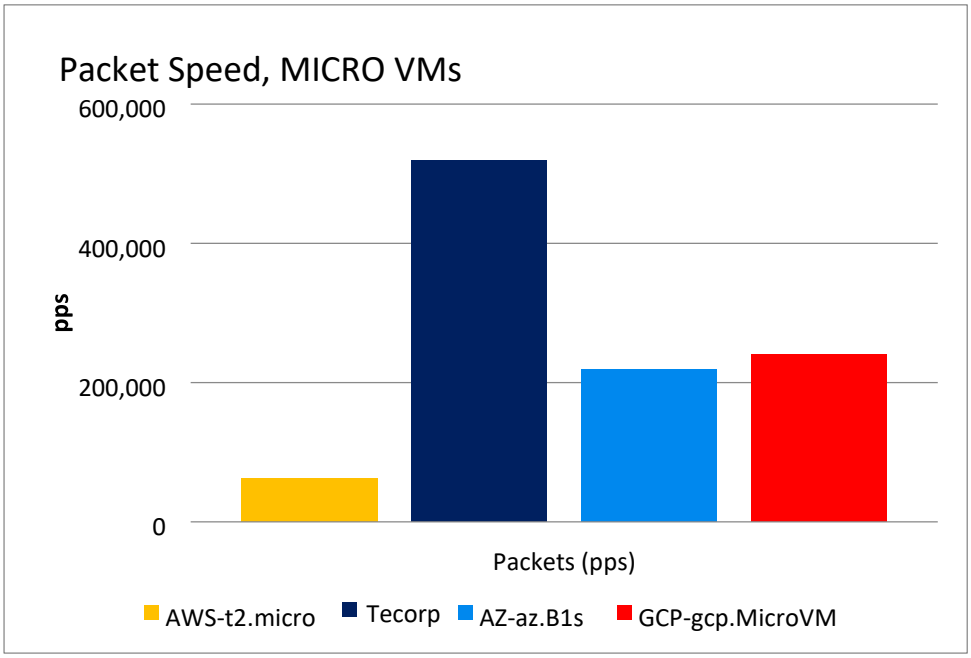
```
ping -c 20000 -q -s 1 -f $2 >> /tmp/results/out.packets
```

NETWORK BENCHMARK RESULTS: MICRO VM

	AWS-t2.micro	Tecorp Group	AZ-az.B1s	GCP-gcp.MicroVM
WAN-Download (Mbits/s)	418	3,655	1725.24	442
WAN-Upload (Mbits/s)	728	1,274	139	131.44
LAN (Gbits/s)	1	9	0.969	2
Packets (pps)	63,314	519,379	218776	240,902

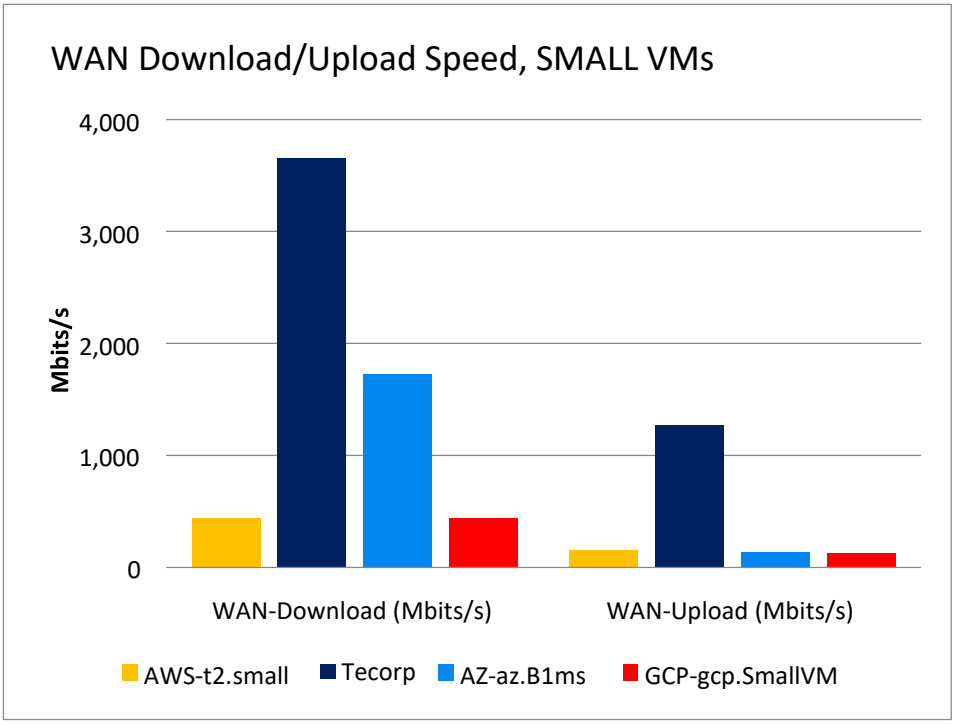

WAN Download/Upload Speed,MICRO
4,000
3,000
2,000
1,000
0
Mbits/s
WAN-Download (Mbits/s)
WAN-Upload (Mbits/s)
AWS-t2.micro
Tecorp
AZ-az.B1s
GCP-gcp.MicroVM

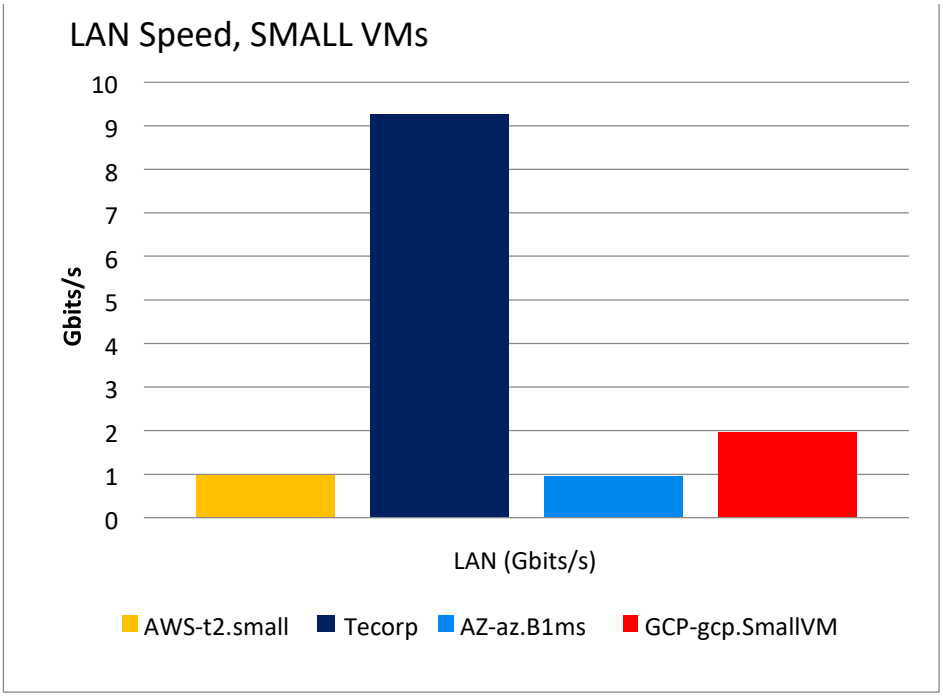

LAN Speed, MICRO VMs
10
8
6
4
2
0
Gbits/s
LAN (Gbits/s)
AWS-t2.micro
Tecorp
AZ-az.B1s
GCP-gcp.MicroVM

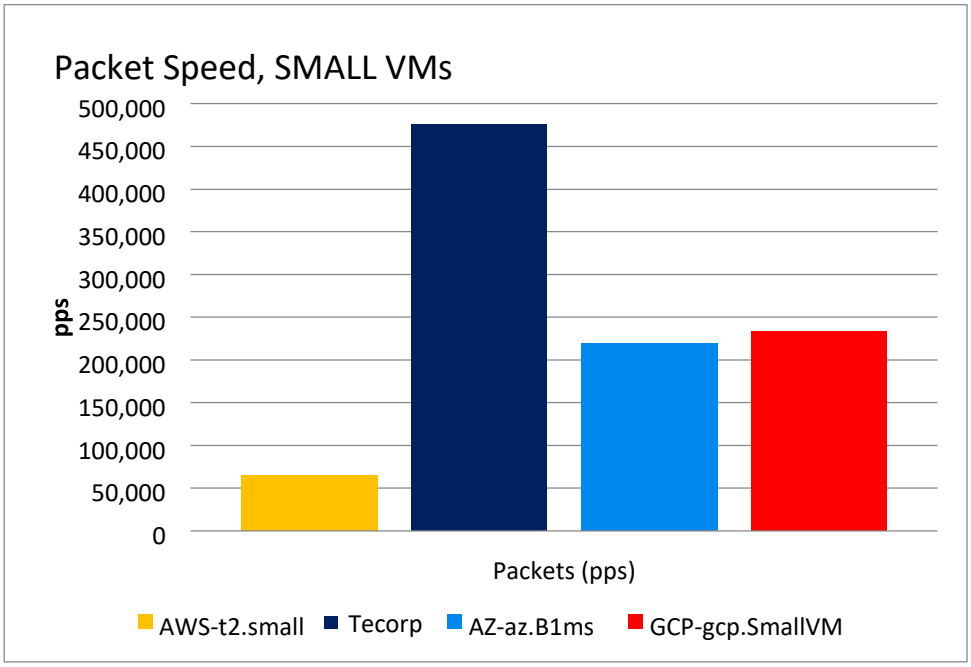


NETWORK BENCHMARK RESULTS: SMALL VM

	AWS-t2.small	Tecorp Group	AZ-az.B1ms	GCP-gcp.SmallVM
WAN-Download (Mbits/s)	437	3,655	1725.24	442
WAN-Upload (Mbits/s)	157	1,274	139	131.44
LAN (Gbits/s)	1	9	0.963	2
Packets (pps)	65,015	475,801	219396	233,601

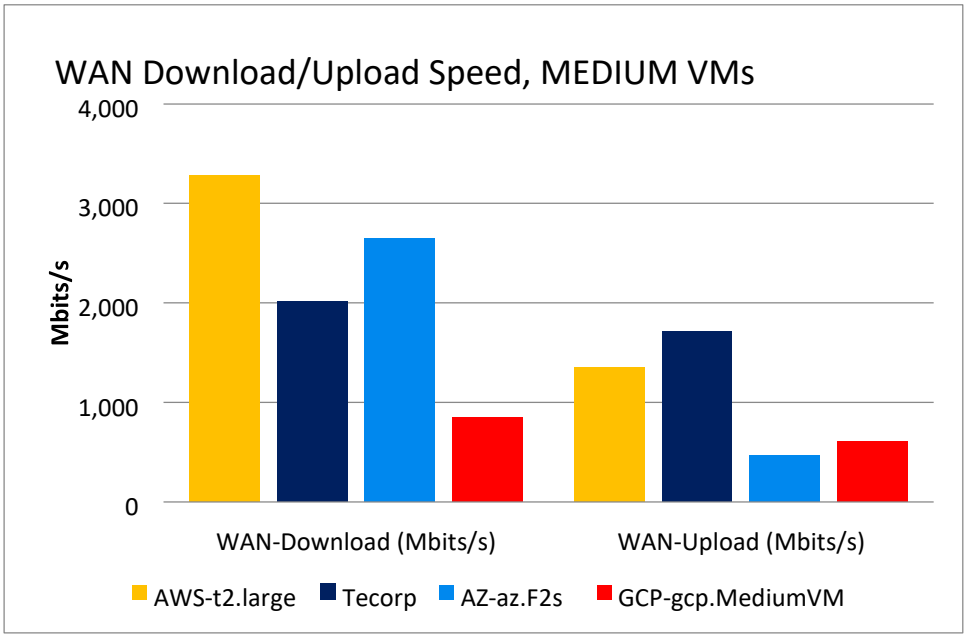

WAN Download/Upload Speed, SMALL VMs
4,000
3,000
2,000
1,000
0
Mbits/s
WAN-Download (Mbits/s)
WAN-Upload (Mbits/s)
AWS-t2.small
Tecorp
AZ-az.B1ms
GCP-gcp.SmallVM

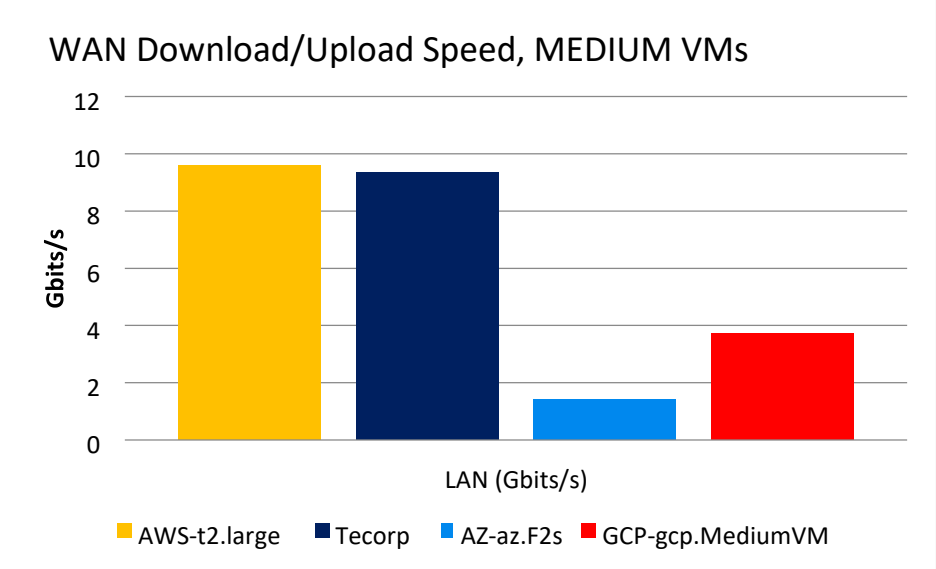

LAN Speed, SMALL VMs
10
9
8
7
6
5
4
3
2
1
0
Gbits/s
LAN (Gbits/s)
AWS-t2.small
Tecorp
AZ-az.B1ms
GCP-gcp.SmallVM

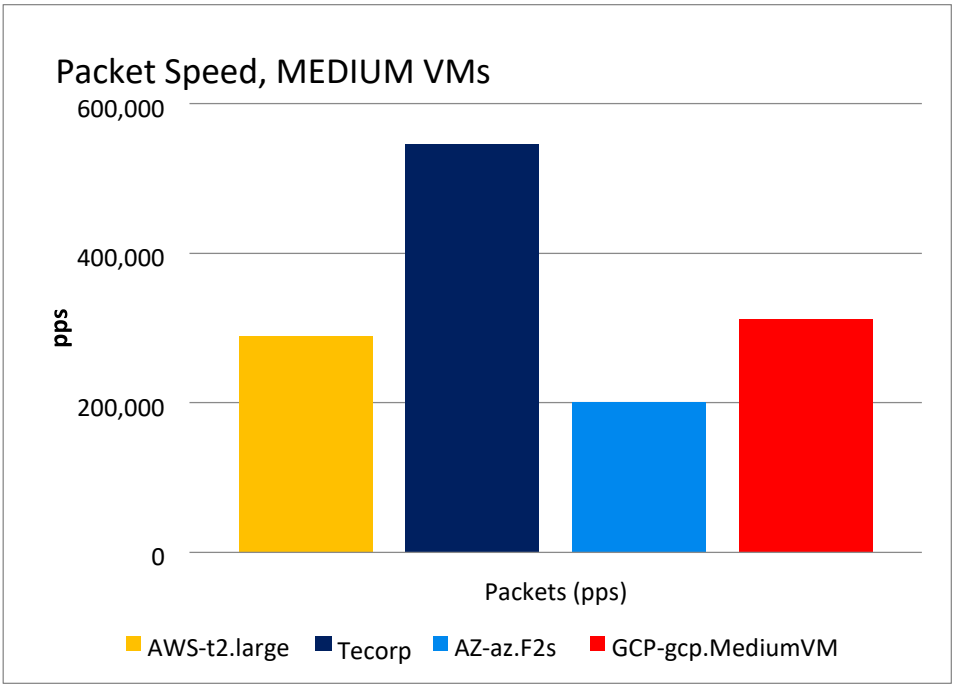


NETWORK BENCHMARK RESULTS: MEDIUM VM

	AWS-t2.large	Tecorp Group	AZ-az.F2s	GCP-gcp.MediumVM
WAN-Download (Mbits/s)	3,278	2,009	2649.08	845
WAN-Upload (Mbits/s)	1,346	1,716	469	609.89
LAN (Gbits/s)	10	9	1.43	4
Packets (pps)	289,408	546,627	201297	312,138

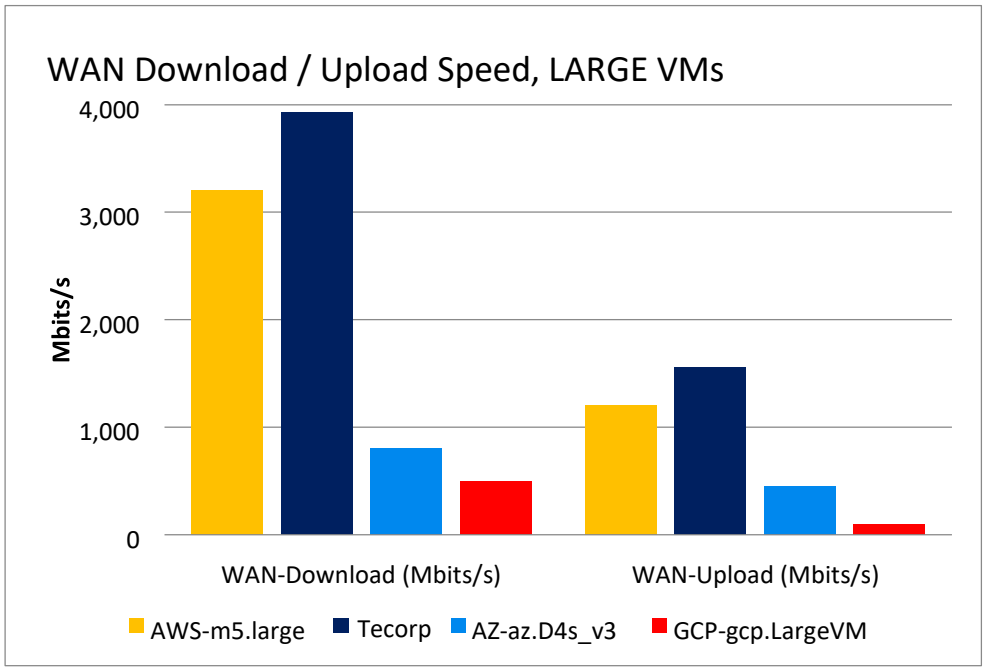

WAN Download/Upload Speed, MEDIUM VMs
4,000
3,000
2,000
1,000
0
Mbits/s
WAN-Download (Mbits/s)
WAN-Upload (Mbits/s)
AWS-t2.large
Tecorp
AZ-az.F2s
GCP-gcp.MediumVM

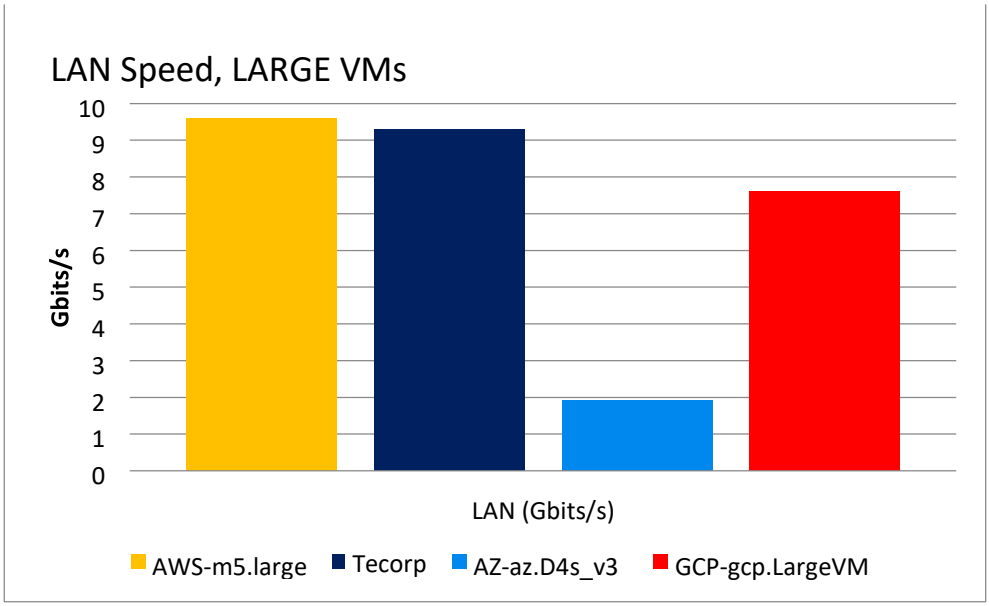

WAN Download/Upload Speed, MEDIUM VMs
12
10
8
6
4
2
0
Gbits/s
LAN (Gbits/s)
AWS-t2.large
Tecorp
AZ-az.F2s
GCP-gcp.MediumVM

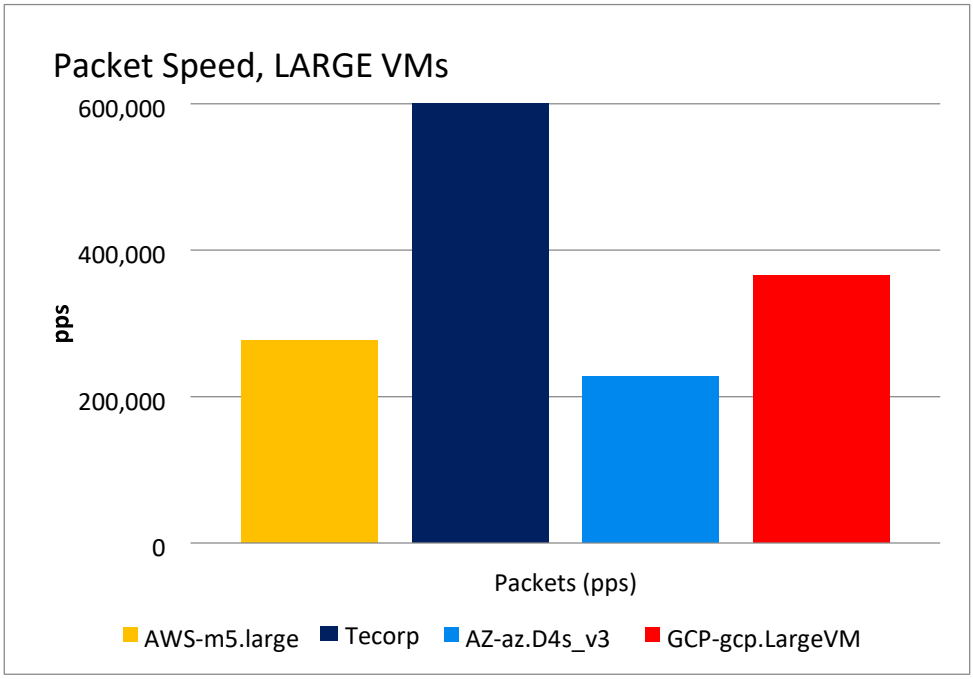


NETWORK BENCHMARK RESULTS: LARGE VM

	AWS-m5.large	Tecorp Group	AZ-az.D4s_v3	GCP-gcp.LargeVM
WAN-Download (Mbits/s)	3,200	3,928	800	500
WAN-Upload (Mbits/s)	1,200	1,557	450	100
LAN (Gbits/s)	10	9	1.91	8
Packets (pps)	276,841	615,219	227800	365,079

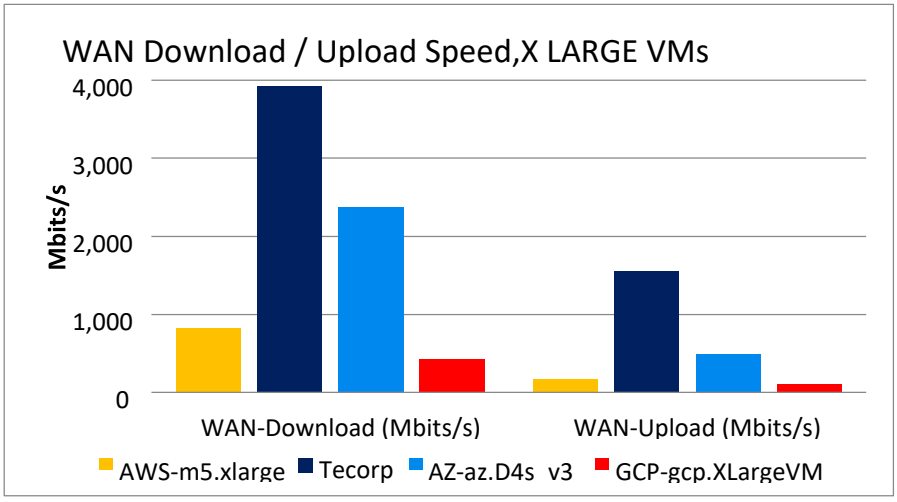

WAN Download / Upload Speed, LARGE VMs
4,000
3,000
2,000
1,000
0
Mbits/s
WAN-Download (Mbits/s)
WAN-Upload (Mbits/s)
AWS-m5.large
Tecorp
AZ-az.D4s_v3
GCP-gcp.LargeVM

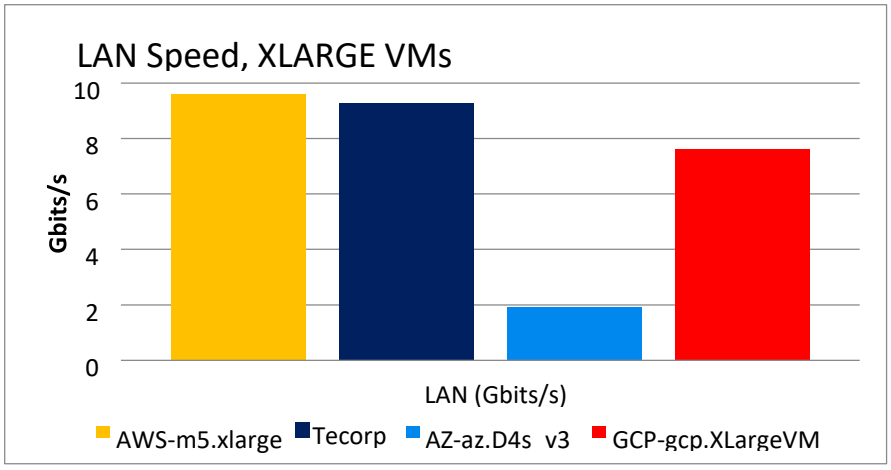

LAN Speed, LARGE VMs
10
9
8
7
6
5
4
3
2
1
0
Gbits/s
LAN (Gbits/s)
AWS-m5.large
Tecorp
AZ-az.D4s_v3
GCP-gcp.LargeVM

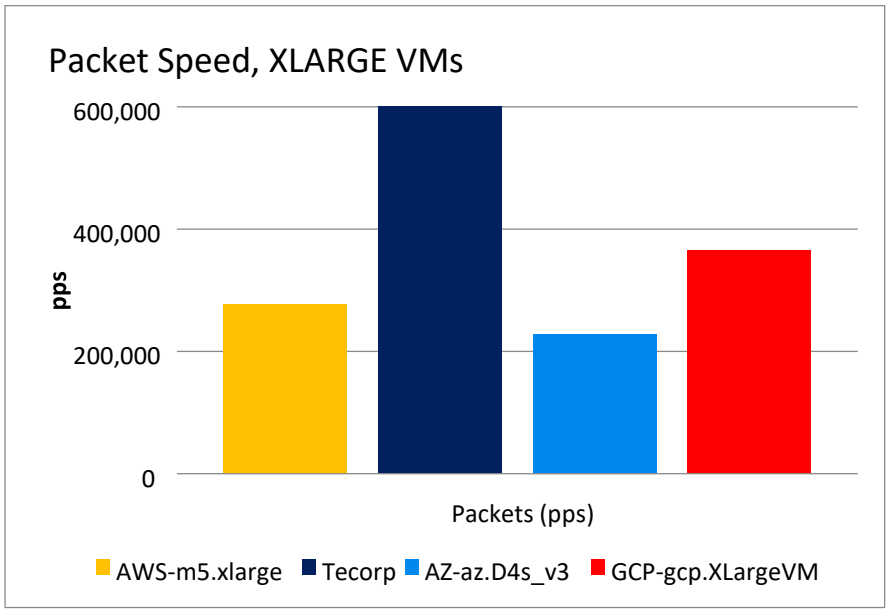


NETWORK BENCHMARK RESULTS: XL VM

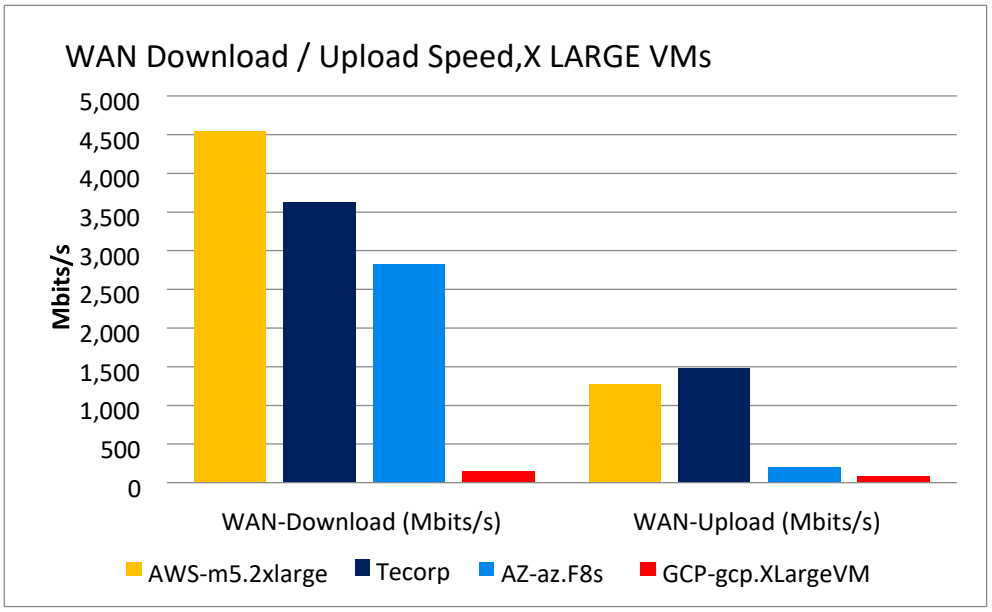
	AWS-m5.xlarge	Tecorp Group	AZ-az.D4s_v3	GCP-gcp.XLargeVM
WAN-Download (Mbits/s)	832	3,928	2372.2	423
WAN-Upload (Mbits/s)	168	1,557	495	106.04
LAN (Gbits/s)	10	9	1.91	8
Packets (pps)	276,841	615,219	227800	365,079

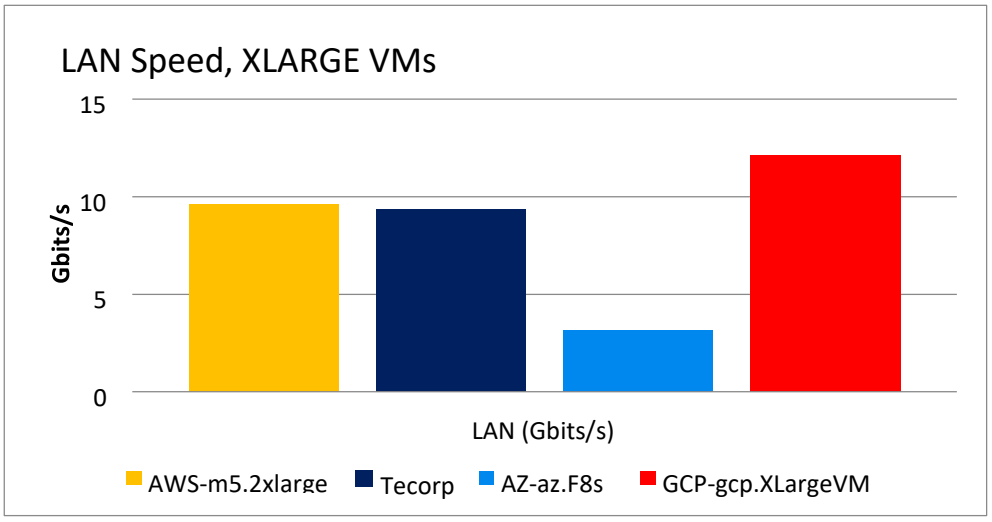

WAN Download / Upload Speed,X LARGE VMs
4,000
3,000
2,000
1,000
0
Mbits/s
WAN-Download (Mbits/s)
WAN-Upload (Mbits/s)
AWS-m5.xlarge
Tecorp
AZ-az.D4s v3
GCP-gcp.XLargeVM

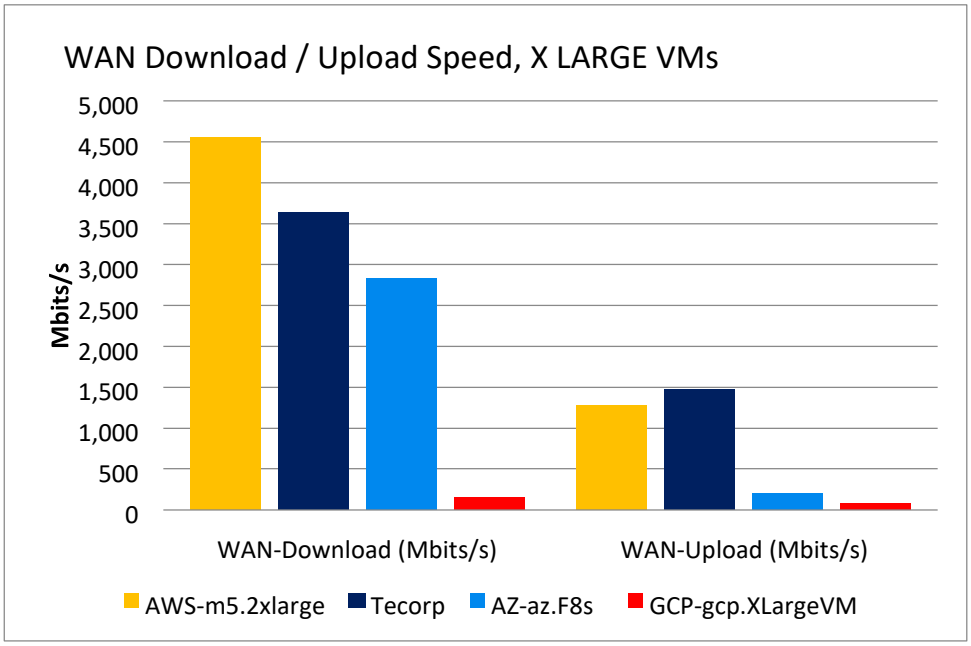

LAN Speed, XLARGE VMs
10
8
6
4
2
0
Gbits/s
LAN (Gbits/s)
AWS-m5.xlarge
Tecorp
AZ-az.D4s v3
GCP-gcp.XLargeVM

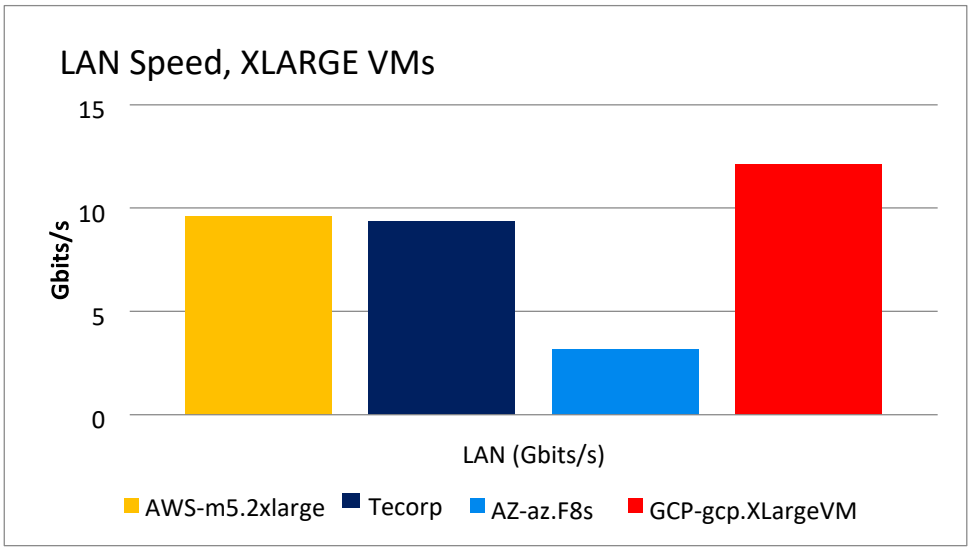

Packet Speed, XLARGE VMs
600,000
400,000
200,000
0
pps
Packets (pps)
AWS-m5.xlarge
Tecorp
AZ-az.D4s_v3
GCP-gcp.XLargeVM

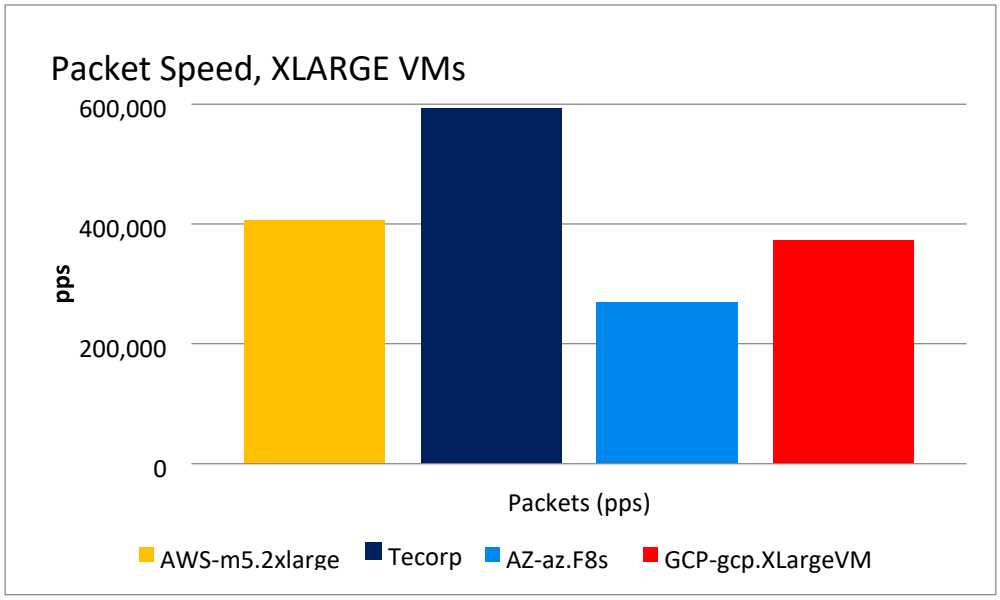
	AWS-m5.2xlarge	Tecorp Group	AZ-az.F8s	GCP-gcp.XLargeVM
WAN-Download (Mbits/s)	4,552	3,632	2833.84	146
WAN-Upload (Mbits/s)	1,273	1,477	191	77.47
LAN (Gbits/s)	10	9	3.17	12
Packets (pps)	405,874	593,973	268913	372,653






WAN Download / Upload Speed, X LARGE VMs
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
Mbits/s
WAN-Download (Mbits/s)
WAN-Upload (Mbits/s)
AWS-m5.2xlarge
Tecorp
AZ-az.F8s
GCP-gcp.XLargeVM


LAN Speed, XLARGE VMs
15
10
5
0
Gbits/s
LAN (Gbits/s)
AWS-m5.2xlarge
Tecorp
AZ-az.F8s
GCP-gcp.XLargeVM



NETWORK BENCHMARK CONCLUSIONS

Tecorp Group's network performance was equivalent to or superior to the other CSPs across all the network parameters that have the greatest impact on performance. Although the AWS WAN download was faster for the Medium and XXL VMs, this is most likely due to differences in the regions on which each CSP was tested.

OVERALL BENCHMARK CONCLUSION

PRICE/PERFORMANCE COMPARISON

As can be seen in the table below, we list all VMs and sizes per provider, per hourly or monthly pricing.

IaaS prices will vary widely for the same CSP depending on the instance category, network traffic volumes, data storage tiering, availability zone location(s), level of upfront payment, usage of reserved instances, spot pricing, and more.

For example, in the largest VM category (XXL), **Tecorp Group's** price per hour is 60% less than the second lowest price (Azure). Similarly, **Tecorp Group's** price per month in the XXL VM category is 45% less than the second lowest price (GCP). Pricing flexibility is also important. **Tecorp Group** does allow month-by-month pricing, while some CSPs' monthly price requires a 12month commitment.

VM Size	Price per Hour (Base traffic and IOPS)				Price per Month (base traffic and IOPS)			
	AWS	TECORP GROUP	AZ	GCP	AWS	TECORP GROUP	AZ	GCP
Micro (1 vCPU / 1 GB RAM)	$0.0134	$0.018	**$0.013**	$0.046	$9.78	$13.14	**$9.49**	$23.58
Small (1 vCPU / 2 GB RAM)	$0.0268	$0.026	**$0.025**	$0.052	$19.56	$18.98	**$18.25**	$26.37
Medium (2 vCPU / 4 GB RAM)	$0.115	**$0.059**	$0.103	$0.103	$83.95	**$43.07**	$75.19	$52.74
Large (4 vCPU / 8 GB RAM)	**$0.115**	$0.121	$0.204	$0.206	**$83.95**	$88.33	$148.92	$117.48
XL (4 vCPU / 16 GB RAM)	$0.23	**$0.186**	$0.24	$0.250	$167.90	**$135.78**	$175.20	$187.80
XXL (8 vCPU / 16 GB RAM)	$0.46	**$0.255**	$0.409	$0.413	$335.80	**$186.15**	$298.57	$270.96

In addition to price per hour or per month, most CSPs add charges per volume and IOPS provisioned, with clear ratios of maximum IOPS permitted per volume size. For example, AWS enforces an IOPS/volume size ratio of 50:1. Thus, if a workload requires 10000 IOPS, on AWS the smallest volume that could be provisioned would be 200GB. The following table compares prices across the four CSPs for both base volumes and volumes provisioned with 1K IOPS:

	AWS	TECORP GROUP	AZ	GCP
Base volume	$5.95	Included in price per hour/month	$3.01	$4.80
Volume provisioned with 1K IOPS	$92.90	Included in price per hour/month	$41.82	$6.94

Summary

The **Tecorp Group** public cloud is comprised of 12 data centers hosted in top tier facilities around the globe including: the UK, Germany, The Netherlands, Israel, Hong Kong, Santa Clara, Texas and New York. With servers operating on VMWare, **Tecorp Group** is a trusted provider to tens of thousands of customers worldwide.

As can be seen in this Benchmark Report, **Tecorp Group's** infrastructure delivers highly competitive performance across all critical cloud parameters such as vCPU speeds, WAN and LAN network speeds, disk IO / bandwidth / IOPS, RAM speed, and more.

Tecorp Group offers advanced cloud infrastructure services and products such as block storage, load balancer, firewall, VPN and more. **Tecorp Group's** management console provides an intuitive single-pane control panel to manage, maintain and supervise all elements of the customer's infrastructure. Tecorp Group can also provide fully managed cloud services such as cloud migration planning and execution, disaster recovery, web servers, and email servers.

Service and flexibility are core values at **Tecorp Group**. Live technical support is available 24/7/365 and **Tecorp Group's** cloud experts can help customers find the optimal solutions for their cloud storage and computing needs. Customers can pay either per hour or a fixed price on a month-by-month basis that includes unlimited bandwidth and IOPS.

Tecorp Group works closely with affiliates and also makes its platform available to partners on a white-label basis through which they can provide a wide range of branded services including VM/IaaS, Cloud LAN, DRP, CDN, WAF, and a full featured marketplace.

To learn more about our company and technology visit our website at www.TecorpGroup.com