Overview

This paper examines the total cost of ownership (TCO) of servers using the Qualcomm Centriq 2400 system-on-chip (SoC) running the Armv8 instruction set architecture (ISA). TIRIAS Research compares an estimated three-year TCO for servers based on the Qualcomm Centriq 2452 SoC against a mainstream x86-based server using Intel Xeon Silver 4110 processors. The performance basis for this comparison is the HHVM web server using the OSS test suite.

Other papers in this series compare the three-year TCO of Redis and estimated SPECrate2017_int_base. Methodology and assumptions for four-paper series are detailed in the companion report *Qualcomm Centriq 2400 Server TCO: Methodology & Assumptions*.

Purpose

The target audiences for this TCO comparison are web hosters and Software-as-a-Service (SaaS) providers. The web serving workload is as old as the World Wide Web, first demonstrated in 1990, and was one of the first web workloads that enterprises offloaded to outside services. However, web hosters and SaaS providers are still competing to improve service and lower costs.

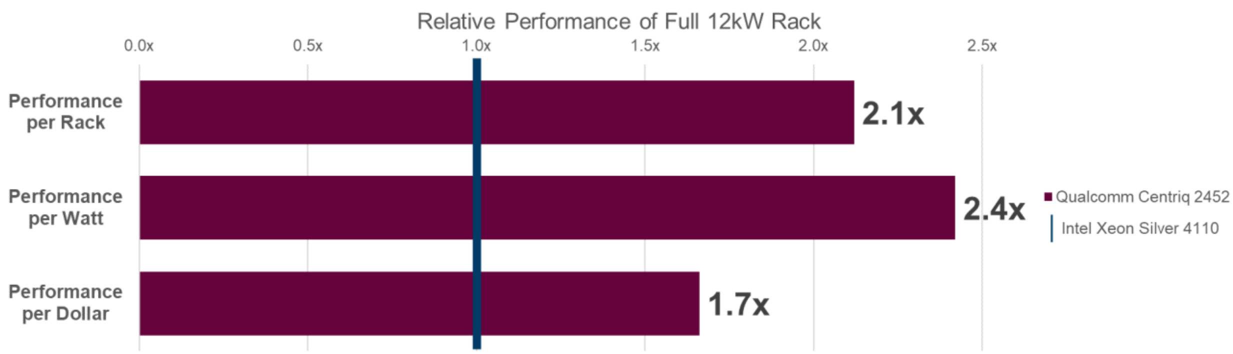
Application

Facebook designed and first deployed HHVM in 2010 to save web server resources in its highly scalable distributed social media content management system. Facebook then open sourced HHVM for a wider community to deploy; it is now a common framework for web serving.

Figure 1 shows that a 12-kilowatt (kW) rack full of two single-socket Qualcomm Centriq 2452 motherboards per chassis (36 chassis total) should have an estimated 2.1x performance advantage and a 1.7x performance per dollar advantage over the 35 dual-socket Intel Xeon Silver 4110 chassis that fit within the rack power limit.

TIRIAS Research observes that servers based on the Qualcomm Centriq 2452 SoC, using two single-socket Qualcomm Centriq 2452 motherboards per chassis, should exceed the Intel Xeon Silver 4110 processor dual-socket motherboard's HHVM performance by 2.1x (Figure 2).

Figure 1: Full 12kW Rack Performance Comparison



Sources: Qualcomm Datacenter Technologies & TIRIAS Research (See Appendix for notes regarding all Figure & Table sources)

Software

The HHVM framework supports the PHP and Hack web scripting languages. Common web applications and their content management systems, such as Drupal, Magento, MediaWiki, and WordPress, are written in PHP (Table 1). HHVM by itself is not a demanding workload; its job is to increase the efficiency of applications written in PHP and Hack. Qualcomm Datacenter Technologies (QDT) used the HHVM OSS suite to benchmark several versions of these widespread web server applications.

Table 1: HHVM OSS Open Source Benchmark Targets

Benchmark	Language	Application Area
Drupal	PHP	Website publishing & content management system for larger organizations
Magento	PHP	Ecommerce shopping cart, order management, & content management system
MediaWiki	PHP	User-modified website publishing & content management system
WordPress	PHP	Website & blog publishing & content management system
Geomean	**Calculated**	**Geometric mean of the above individual metrics**

Source: TIRIAS Research

HHVM's intermediate byte code architecture presents a clean abstraction layer to substitute the Armv8 instruction set architecture (ISA) for the default x86 ISA in HHVM's bytecode to machine code just-in-time compiler. To do so required some shared libraries not included in the libvent yum package (see Appendix).

Hardware

QDT benchmarked one single-socket Centriq 2452 motherboard against a one Intel Xeon Silver 4110 dual-socket motherboard. The Intel Xeon Silver 4110 processor and dual-socket motherboard are representative of HHVMM solutions often bought by cloud customers.

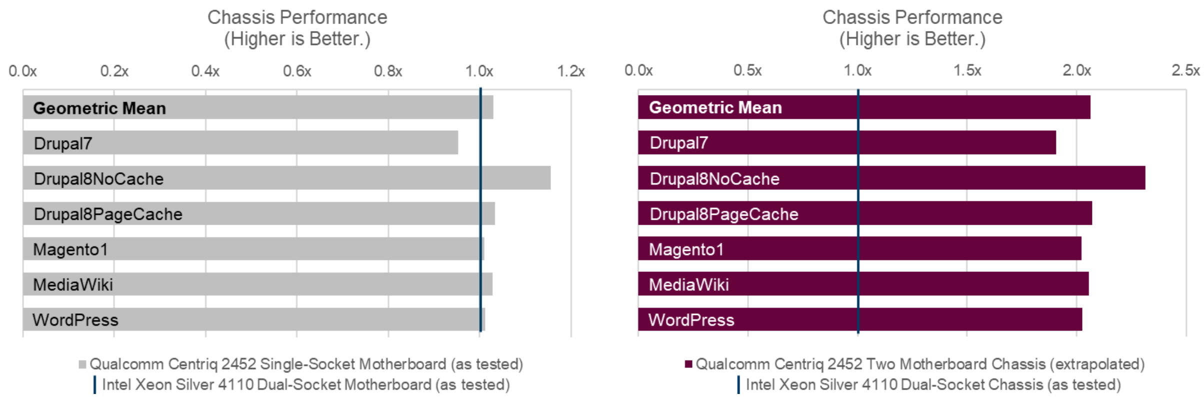
QDT chose to use 32 GB memory density and DDR4-2400 speed on the tested Qualcomm Centriq 2452 motherboard for socket to socket memory parity with the Intel Xeon Scalable configuration. The HHVM benchmark tool runs entirely in memory on one motherboard. Network and storage performance do not factor into its performance results. QDT measured processor socket power consumption while running the HHVM benchmark tool.

TIRIAS Research extrapolated QDT's single-socket measurements to estimate performance and power consumption for two single-socket Qualcomm Centriq 2452 motherboards in a chassis. In this case, benchmarking two identical motherboards in the same chassis results in 2.1x the benchmark score.

To show a more accurate TCO comparison for performance per watt consumed, this analysis burdened the processor-based power consumption comparison with estimates for complete chassis-level power consumption.

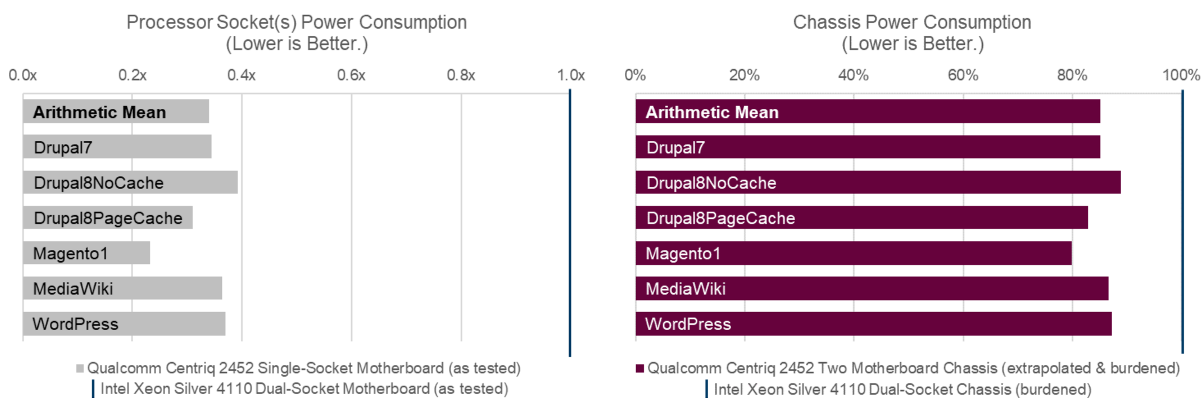
Results

Figure 2: HHVM Performance



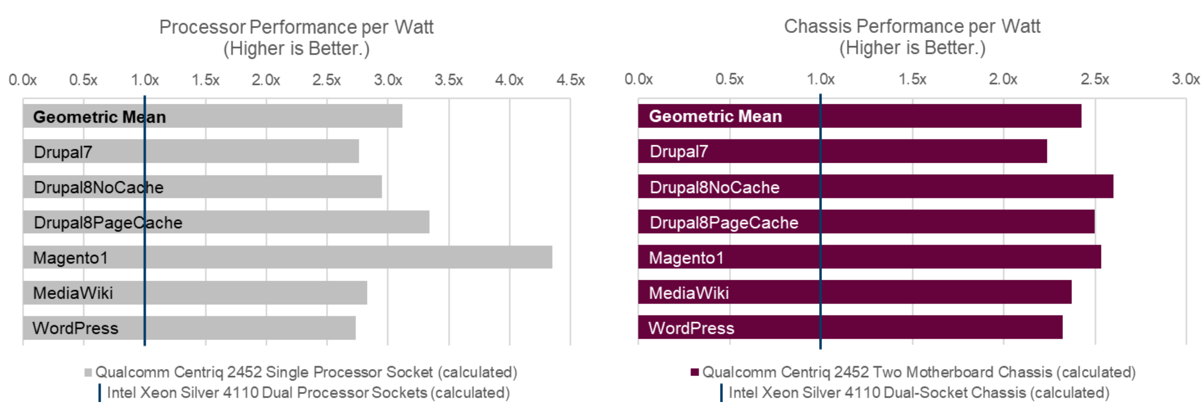
Sources: Qualcomm Datacenter Technologies & TIRIAS Research

Figure 3: HHVM Power Consumption



Sources: Qualcomm Datacenter Technologies & TIRIAS Research

Figure 4: HHVM Performance per Watt



Sources: Qualcomm Datacenter Technologies & TIRIAS Research

See Appendix for a summary of the measured data.

TCO Analysis

TIRIAS Research reduces TCO analysis to the smallest set of variables that highlight useful differences between products. For server processor TCO calculations, the number of constants that apply to both configurations in the comparison were simplified. Because processors cannot run workloads without the rest of a functioning server, the measured performance, power consumption, and hardware bill of materials costs were extrapolated and burdened to obtain capital expense (Capex) and operating expense (Opex) estimates.

These tests do not extend the TCO estimate beyond evaluating simple rack-scale metrics, because identical switches, power distribution, cabling, and rack costs would be used for both configurations.

Two Single-Socket Qualcomm Centriq 2400 Motherboards per Chassis

Table 2 shows rack-level extrapolations of a three-year TCO based on a 12kW rack power supply. 1kW was subtracted for two (redundant) top of rack (TOR) switches, leaving 11kW available to power servers. The HHVM benchmark results for individual server chassis were multiplied by the number of server chassis that can be run within 11kW.

A full rack of 36 Qualcomm Centriq 2452 chassis each containing two single-socket motherboards fits within a 12kW rack power budget—in fact, 41 chassis fit within that power budget, but only 36 will physically fit in a rack (Table 2 & Figure 5). 35 dual-socket Intel Xeon Silver 4110 chassis fit in the same power budget. A full rack of Qualcomm Centriq 2452 servers should show 2.1x better performance than 35 dual-socket Intel Xeon Silver 4110 chassis, at only 1.3x the price and 0.9x the power consumption. Buying fewer servers to meet performance goals may also lower IT software and hardware management costs.

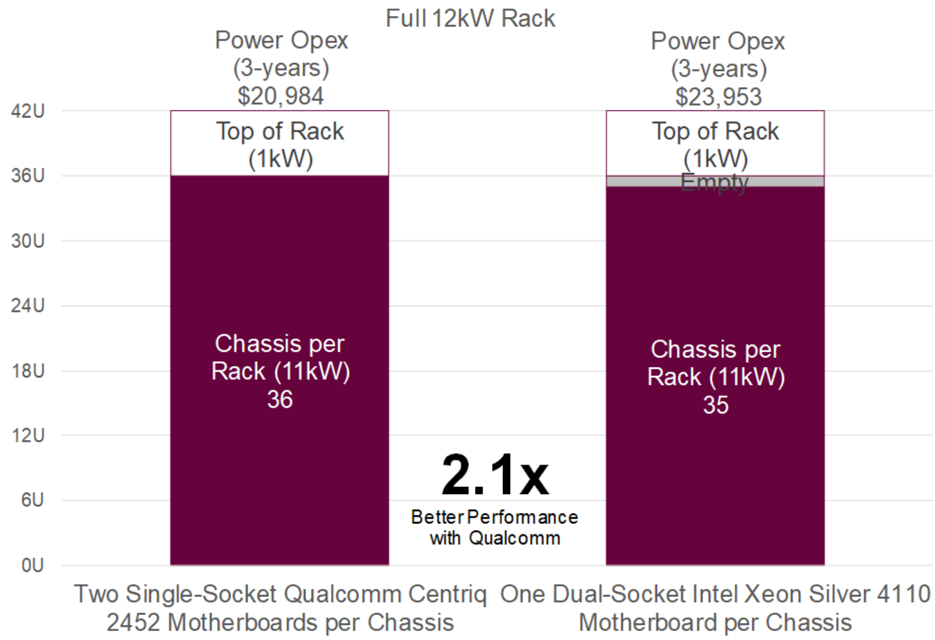
Table 2: TCO Based on HHVM

TCO		Two Motherboards† Single-Socket Qualcomm Centriq 2452	One Motherboard†† Dual-Socket Intel Xeon Silver 4110	Difference	Maximum Chassis within 11kW Power Budget: 36 Chassis Qualcomm Centriq 2452	35 Chassis Intel Xeon Silver 4110	Difference
Capex	Processor(s)	$2,746	$1,000	2.7x	$98,856	$35,000	2.8x
	Memory	$3,574	$3,574	1.0x	$128,670	$125,095	1.0x
	Motherboard	$935	$820	1.1x	$33,660	$28,700	1.2x
	Storage	$154	$77	2.0x	$5,530	$2,688	2.1x
	NIC	$360	$180	2.0x	$12,960	$6,300	2.1x
	Rest of Server	$290	$290	1.0x	$10,440	$10,150	1.0x
	Infra Power Cost (3yr)	$919	$1,079	0.9x	$33,085	$37,765	0.9x
Opex	Power (3yr)	$583	$684	0.9x	$20,984	$23,953	0.9x
	Total	**$9,561**	**$7,704**	**1.2x**	**$344,185**	**$269,651**	**1.3x**
	Performance	**2,319**	**1,125**	**2.1x**	**83,471**	**39,365**	**2.1x**

†extrapolated ††as tested

Sources: Qualcomm Datacenter Technologies & TIRIAS Research

Figure 5: Compute Density & Power Opex within 12kW Rack



Sources: Qualcomm Datacenter Technologies & TIRIAS Research

One Single-Socket Qualcomm Centriq 2400 Motherboard per Chassis

72 Qualcomm Centriq 2452 chassis each containing one single-socket motherboard also fits within a 12kW rack power budget, but again, only 36 will physically fit in a rack (Table 3 & Figure 6). A full rack of Qualcomm Centriq 2452 servers each with only one motherboard should show the same performance as 35 dual-socket Intel Xeon Silver 4110 chassis, but at only half the power consumption and 0.7x the price.

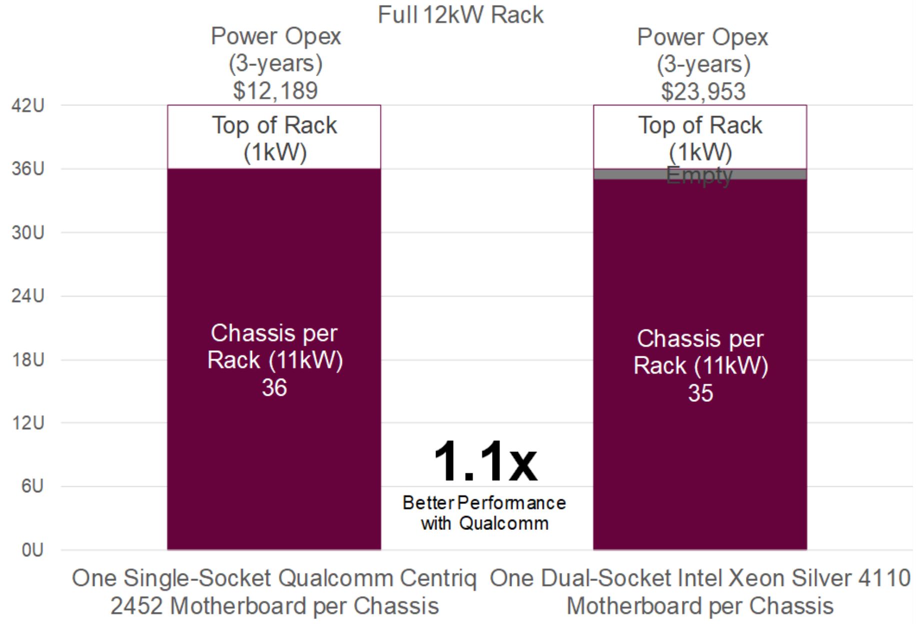
Table 3: TCO Based on HHVM: One Single-Socket Qualcomm Centriq 2400 Motherboard per Chassis

TCO		One Motherboard†† Single-Socket Qualcomm Centriq 2452	One Motherboard†† Dual-Socket Intel Xeon Silver 4110	Difference	Maximum Chassis within 11kW Power Budget: 36 Chassis Qualcomm Centriq 2452	35 Chassis Intel Xeon Silver 4110	Difference
Capex	Processor(s)	$1,373	$1,000	1.4x	$49,428	$35,000	1.4x
	Memory	$1,787	$3,574	0.5x	$64,335	$125,095	0.5x
	Motherboard	$460	$820	0.6x	$16,560	$28,700	0.6x
	Storage	$77	$77	1.0x	$2,765	$2,688	1.0x
	NIC	$180	$180	1.0x	$6,480	$6,300	1.0x
	Rest of Server	$290	$290	1.0x	$10,440	$10,150	1.0x
	Infra Power Cost (3yr)	$534	$1,079	0.5x	$19,217	$37,765	0.5x
Opex	Power (3yr)	$339	$684	0.5x	$12,189	$23,953	0.5x
	Total	**$5,039**	**$7,704**	**0.7x**	**$181,414**	**$269,651**	**0.7x**
	Performance	**1,159**	**1,125**	**1.0x**	**41,736**	**39,365**	**1.1x**

††as tested

Sources: Qualcomm Datacenter Technologies & TIRIAS Research

Figure 6: Compute Density & Power Opex within 12kW Rack: One Single-Socket Qualcomm Centriq 2400 Motherboard per Chassis



Sources: Qualcomm Datacenter Technologies & TIRIAS Research

Conclusion

Using the HHVM benchmark results to generate a rack-level three-year TCO comparison of the Qualcomm Centriq 2452 SoC against the Intel Xeon Silver 4110 processor allows a fair comparison of the selected modern cloud workloads. The Qualcomm Centriq 2452 SoC shows 1.6x to 1.7x greater estimated performance per dollar than Intel Xeon Scalable in this comparison (one motherboard to two motherboards), based on its HHVM benchmark performance and power consumption. However, actual TCO will vary widely in practical use.

In a nutshell, web server customers have two good choices using Qualcomm Centriq 2452:

- Maximize rack density using two motherboards per chassis, for a 2.1x rack-level performance advantage at 1.3x Intel Xeon Silver 4110 three-year TCO, so it will take longer to fill a datacenter to capacity within Capex and Opex constraints. Similarly, a smaller datacenter can be designed to meet a specific level of compute performance.
- Minimize rack TCO using one motherboard per chassis, for a slight 1.1x bump in performance at 0.7x the total three-year TCO, with half the rack-level power consumption.

Companies deploying in-memory database workloads should consider benchmarking their workloads on Qualcomm Centriq 2400 Armv8-based servers.

Appendix

Figure & Table Sources

Unless otherwise noted, all Figures and Tables are based on Qualcomm Datacenter Technologies (QDT) benchmark measurements, Qualcomm Centriq 2400 SoC and motherboard specifications, public competitive processor, motherboard, and chassis specifications, and TIRIAS Research calculations and formatting.

Table A1: Summary of Measured Data

HHVM	Qualcomm Centriq 2452 Single-Socket Motherboard		Intel Xeon Silver 4110 Dual-Socket Motherboard	
	Chassis Performance	Processor Socket Power Consumption	Chassis Performance	Processor Sockets Power Consumption
Drupal7	1,527	42.7	1,603	123.8
Drupal8NoCache	691	47.3	598	120.6
Drupal8PageCache	6,394	35.7	6,180	115.2
Magento1	305	21.0	302	90.3
MediaWiki	1,068	44.0	1,038	120.9
WordPress	1,105	44.3	1,092	119.7
Geometric Mean	**1,159**	**n/a**	**1,125**	**n/a**
Arithmetic Mean	**n/a**	**39.2**	**n/a**	**115.1**

Source: Qualcomm Datacenter Technologies

Source Code

HHVM source code was checked out from https://github.com/facebook/hhvm. Benchmark source code was checked out from https://github.com/hhvm/oss-performance using the April 19, 2017 commit (9b1a334), available immediately after the HHVM 3.19.1 release. MariaDB server and related files were installed via CentOS's yum package manager (mariadb-server-5.5.56-2.el7.aarch64).

Script to Run HHVM OSS

Disable SELinux by editing /etc/selinx/config and reboot

Boot system:

```
sudo systemctl start mariadb
 for file in /sys/devices/system/cpu/cpu*/cpufreq/scaling_governor; do
        sudo -- sh -c "echo performance > $file"
    done
echo 1 | sudo tee /proc/sys/net/ipv4/tcp_tw_reuse
hhvm batch-run.php < batch-run-local.json > batch-run-local-output.json
hhvm batch-run.php < batch-run-local-nra.json > batch-run-local-nra-output.json
hhvm json_to_csv.php batch-run-local-output.json
hhvm json_to_csv.php batch-run-local-nra-output.json
```

Repeat HHVM runs for 3 iterations and additional WordPress runs until 3 scores exceed 1000

Re-enable SELinux by editing /etc/selinx/config and reboot

Additional Libraries Installed from Source Code

Cmake 3.6.2:

./bootstrap --prefix=/usr/local/ ; make ; sudo make install

Oniguruma v6.3.0:

Replace 1.14 by 1.13 in line 6 of configure.ac

autoreconf -vfi ; ./configure --prefix=/usr/local/ ; make ; sudo make install

Mcrypt 2.5.8:

autoreconf -vfi ; ./configure --prefix=/usr/local/ ; make ; sudo make install

Boost 1.60:

./bootstrap.sh --prefix=/usr/local ; sudo ./b2 install

Libglog v0.3.4:

autoreconf -vfi ; ./configure --prefix=/usr/local ; make ; sudo make install

Jemalloc 4.5.0:

autoreconf -vfi ; ./configure --prefix=/usr/local/ ; make ; sudo make install

Siege: version 2.78:

autoreconf -vfi ; ./configure --prefix=/usr/local/ ; make ; sudo make install