



Research Report

The Major Difference Between IBM's LinuxONE and x86 Linux Servers

Executive Summary

The most important point in this *Research Report* is this: *mainframes process certain Linux workloads more efficiently than x86 servers*. Mainframe processors work differently than x86 processors, and, when combined with the mainframe “shared everything” highly scalable system design and an extensive input/output (I/O) subsystem – mainframes can outperform x86 processors while offering greater Quality-of-Service (QoS).

Background

Most information technology (IT) executives believe that the Linux operating environment should be run on x86-based servers – and refuse to believe that an IBM LinuxONE server is better suited from an efficiency perspective to run certain Linux workloads. *IT executives in this x86 camp should stop reading this report now.*

For those still reading, *Clabby Analytics* believes that there is a substantive case to adopt IBM LinuxONE servers for Linux workloads that require scale; that can benefit from large cache “stacked” processing; and that require industry-leading QoS levels (reliability, availability, security, ...).

In mid-2015, Robert Francis Group (RFG) produced the best research report on IBM's LinuxONE platforms that we have ever seen. Entitled “[10 Reasons LinuxONE is the Best Choice for Linux Workloads](#)”, this report articulates why IBM LinuxONE enterprise servers are better than x86-based servers when it comes to agility/flexibility, scalability, availability, security, staffing /productivity/skills, disaster recovery, performance, stability, investment protection and support.

We strongly believe every argument put forward in the RFG report. We would, however, like to delve more deeply into one aspect of IBM LinuxONE: its microprocessor/system design. Further, we would like to add one more advantage to the RFG list: the business partner ecosystem that supports IBM's LinuxONE initiative.

In this *Research Report*, *Clabby Analytics* explains why LinuxONE can process certain Linux workloads far more efficiently than x86-based servers (one major reason is a concept known as “stacking”). We then discuss certain system design advantages that LinuxONE has over typical x86 server implementations (shared everything architecture). We conclude with comments on the growing role of business partners in the LinuxONE ecosystem (we are seeing this ecosystem grow rapidly as business partners seize opportunities to improve Linux workload performance while lowering computing costs).

The Major Difference Between IBM LinuxONE and x86 Linux Servers

First Things First: What is LinuxONE?

In its report, the Robert Francis Group refers to LinuxONE offerings as “low-cost, scale-up enterprise servers”. We prefer to be more blunt: *LinuxONE servers are Linux-only mainframe servers*. To be perfectly clear, LinuxONE servers are IBM z System servers (also known as z13 servers) that have been designed and qualified to support and run Red Hat, SUSE and/or Ubuntu Linux operating environments.

The reason why we so strongly emphasize that LinuxONE servers are mainframes is because there are substantial differences in the way that a mainframe processes Linux workloads as compared to the way that an x86 server processes Linux workloads (see next subsection).

There are two LinuxONE server models (named after penguin species): 1) Rockhopper (for mid-sized enterprises); and, 2) Emperor (for large enterprises):

- Rockhopper runs on a 4.3 GHz processor that can support up to 20 customer-configurable LinuxONE cores. It also features 264 dedicated cores that are used for input/output and high availability. This system can support over a thousand virtual machines in a single footprint. As will be discussed in depth in the next section, it supports a multilevel cache subsystem – and it provides access to up to 4TB of main memory.
- Emperor uses a 5.0 GHz processor, supports up to 141 customer-configurable cores; and supports input/output and high availability using 667 dedicated cores. This system can support up to 8,000 virtual machines. And, like Rockhopper, it offers a multi-level cache – but with access to a total of 10TB of main memory. Also, it should be noted that this system can deliver up to 2.2x the performance for SQL and NoSQL databases as compared with x86-based servers.

The Most Important Difference Between LinuxONE and x86-based Servers: Stacking

The primary difference between the way that a mainframe “z” processor (a z13 processor unit chip) executes workloads and the way an x86 server executes workloads is a concept known as “stacking”. Stacking refers to running multiple virtualized workloads in an OS image in cache where it can be executed more quickly than data coming in from memory.

For those not familiar with cache, a cache is hardware used by a microprocessor to reduce the time and energy it takes to access data from memory. In short, it is a level of memory placed on or close to a central processing unit that stores copies of data found in frequently used locations in main memory:

- Mainframes z processors utilize four levels (L1 offers 96KB for instructions and 128KB for data; L2 offers 2MB for instructions and 2MB for data; L3 offers 64MB of store-in shared cache; and 480 MB of cache can be found off-chip) of large cache to stack data close to the microprocessor – and then use the fastest processors in the industry to execute threads of work. IBM LinuxONE Emperor has over 4X more on-chip cache than x86 processors. And x86 processors do not have access to L4 cache.

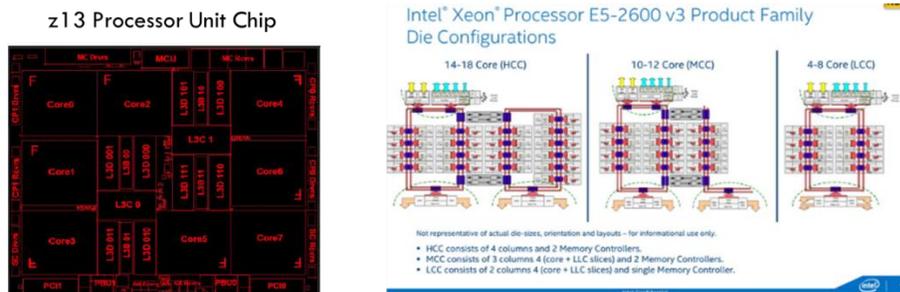
The Major Difference Between IBM LinuxONE and x86 Linux Servers

- x86 processors offer far less cache – but use a lot of processor cores to execute threads. As an example, the 18 core E5 2699 V3 chip can access 32KB of L1 cache per core (18 X 32KB); 32KB of L2 cache per core (18 X 32KB); and 45MB of L3 shared cache.
- *Notice the differences in the cache size of each architecture. IBM measurements are mostly in megabytes; Intel measurements are mostly in kilobytes.*

Figure 1 compares the cache in each processor environment.

Note that in the comparison above we chose to use a E5 266 v3 processor for comparison. We chose this chip because its supports a lot of cores, and – compared to other members of the E5 family – a lot of cache. But the number of cores and the amount of cache varies by chip in the E5 family. A complete list of E5 v3 microprocessor specifications including processor frequencies and available cache can be found in this Intel [report](#).

Figure 1 – Workload Processing: Mainframes Microprocessors vs. x86 Microprocessors



L1 – 96KB for instructions
128KB for data

L2 – 2MB for instructions
2MB for data *

L3 – 64MB of store-in shared *

L4 – 480MB off-chip *

Cache varies by model from 15-45MB
(Using E5 2699 V3 below as example)

L1 – 18 X 32KB

L2 – 18 X 32KB

L3 – 45 MB shared SmartCache

* Notice z advantages in the amount of cache and notice cache sizes in MB, not KB

Source: Compiled by Clabby Analytics from IBM and Intel slides – June, 2015

The key takeaway here is that IBM’s z processor offers significantly more cache – allowing LinuxONE to stack multiple workloads and run more virtual machines (up to 20 per core) on Linux on z processors – thus allowing the z processor to execute work more efficiently. Intel has less cache – but throws a lot of processing power at executing workloads.

As a rule-of-thumb, consider the following advice:

- **If a Linux workload runs in a steady, sustained fashion, then it can best be served by an x86 server that can methodically process large numbers of threads.**

The Major Difference Between IBM LinuxONE and x86 Linux Servers

- *However, if the workload is variable (and multiple workloads can be placed into cache in order to increase utilization), then these variable workloads are best served by the large cache, very fast processors found in LinuxONE servers.*

The reason that this “stacking” discussion is important is related to IT efficiency. If one systems environment can process a workload exponentially faster than another systems environment, then it should be chosen to execute that workload in order to save money.

According to the RFG report described earlier: the TCO for Linux applications on x86 servers can be more than 65% more expensive than on LinuxONE servers. Further, an internal IBM study compared the cost of running Web application workloads on a LinuxONE private cloud vs. an x86 private and an x86 public cloud environments (running general purpose virtual machines) and found the LinuxONE environment to be 45% lower in cost.

To us, these examples represent huge saving in TCO that can be achieved by simply choosing the right system to handle the right workloads.

The “Shared Everything” Discussion

The design point of the System z mainframe has long been to maximize utilization through the sharing of resources (compute, memory, disk, and communications). This is why the mainframe is known as a “shared everything” architecture.

The design focus in shared nothing designs is raw throughput, so systems are designed to allow systems engineers to dedicate resources to processors in order to increase performance. Because other programs are not allowed to use these resources once they have been claimed, applications own resources and don’t share readily. For years x86 servers were being deployed as “shared nothing” environments. These servers essentially locked resources such as input/output and memory in order to ensure that a given server could maximize throughput. In shared nothing designs, if a resource goes unused, it is wasted – but if a resource goes fully used for long periods of time, then an x86 server performs well from an efficiency and ROI point of view.

The reason that this “shared resource” discussion is important is because shared everything designs offer high resource utilization. LinuxONE servers can run at 100% utilization for long sustained periods.

Shared nothing machines can be oriented to drive raw throughput – but in this mode overall system resource utilization will likely not be as high as a shared nothing architecture.

Note that about a decade ago typical shared nothing designs used to run in the 5-20% utilization range because they did not return unused resources to a resource pool where those resources could be shared. Today, thanks to advances in x86 server virtualization and cloud architecture, we typically see x86 servers running in th 40-50% utilization range.

The Major Difference Between IBM LinuxONE and x86 Linux Servers

Think about the preceding paragraphs a bit more. If Linux on LinuxONE servers can run at 100% utilization – and if x86 servers are running (optimistically) at 50% utilization – this means that it takes about twice as many x86 servers to execute the same workloads as a LinuxONE server. And underutilization has a ripple effect as can be seen in this 2011 [report](#) that we have just republished. In this report we showed how it cost almost a million dollars more to run the same workload on x86 servers versus running them on a mainframe. And the key culprits in the extraordinary price differential between x86 servers and mainframes were the need for more software licenses, more systems and more networking equipment with the x86-based solutions.

In our 2011 report we also noted that “smaller scale servers (such as Intel Xeon multi-cores) do not have as large a base of resources available in a common pool (CPU, memory, and I/O is bounded within each server). And, as a result, smaller scale servers need to be over-provisioned (more headroom needs to be allocated) to handle usage peaks and valleys within a given small server environment.” This comment is still valid today. With large pools of resources (such as the 10TB of main memory offered on a z System) there is an opportunity to serve more and more virtual machines than on a system without similar pooled resources.

The Partner Ecosystem Discussion

Last October, *Clabby Analytics* attended IBM’s “Insight 2015” conference in Las Vegas. This is a data/analytics conference designed to showcase IBM and business partner technologies that pertain to information management, data analytics, cognitive computing and more. At this conference, on the trade show floor, several LinuxONE business partners had congregated in their own section. When we spoke to these vendors we noted how enthusiastic they were about being able to deploy their solutions on powerful LinuxONE servers.

As could be expected, representatives from the three major Linux distributions were in attendance at Insight 2015: SUSE, Canonical-Ubuntu, and Red Hat. Cloud infrastructure makers from the open source community included OpenStack, Chef and Docker representatives. Booths also demonstrated KVM, z/VM and IBM Dynamic Partition Manager. From an application development environment perspective, we did not see Node.js, Java, Ruby, Rails, Erlang, Python or Open JDK represented – but all of these development environments are supported on LinuxONE. From a database perspective, MariaDB, MongoDB, IBM Cloudant and Apache Cassandra could be found at the event – but PostgreSQL and Apache CouchDB also run in LinuxONE environments. The bottom line on LinuxONE at Insight 2015 is this: we are seeing a vibrant business partner ecosystem develop around LinuxONE – with strong participation from the open source community.

When we asked several of these vendors what they think of LinuxONE, they told us that they were seeing strong performance results by hosting their software on the recently introduced LinuxONE servers. Some results include larger populations of virtual machines that are able to achieve 2X better performance than Intel Haswell x86-based servers. Figure 2 (next page) describes some of the more impressive results.

The Major Difference Between IBM LinuxONE and x86 Linux Servers

Figure 2 – IBM Business Partner Results: LinuxONE

IBM LinuxONE Emperor demonstrates advantage in multiple tests ¹	
Docker	A LinuxONE Emperor runs 2000+ Docker containers on average 2.0x better than a compared Haswell-based system ²
IBM WebSphere® Application Server Liberty	1.5x better throughput versus a compared x86 platform running DayTrader 3, exploiting SMT and SIMD technology ³
MariaDB	MariaDB has a scaling efficiency of 84% up to 32 hardware threads (16 cores). Open Source products show an excellent scaling efficiency
MongoDB	Up to 2.4x higher throughput versus a compared x86 system running the Yahoo Cloud Service Benchmark (YCSB) ⁴
Spark	Up to 50% higher performance using Spark 1.4.0 versus a compared x86 platform ⁵

Source: IBM Corporation – June, 2016

Summary Observations

For at least a decade we have argued that workload characteristics should dictate processor choice – and that no single microprocessor is ideal for all jobs. Accordingly, IT executives should understand the differences between a z processor and an x86 processor in order to make the most optimal choice for executing various workloads.

The way that LinuxONE (mainframe) z processors process work is distinctly different from the way that x86 processors process work. In short, some microprocessors focus on processing large numbers of threads (examples: x86, POWER and SPARC) – while the z microprocessor focuses on placing data in large cache and then quickly executing threads (a process known as stacking).

If a workload runs in a sustained mode for long periods of time, it benefits from an approach that uses a large number of cores to process a large number of threads. However, if a workload is variable (peaks in demand, changing memory requirements, etc.), it benefits from being able to use larger LinuxONE caches to drive more virtual machines and gain easier access to pooled resources.

The reason this difference is important has to do with utilization efficiency: if a workload can make sustained use of system resources for long periods of time, it is more efficient to use high-threading parallel processing approach. However, if the workload varies its use of system resources, it is best served by a stacking approach. So, if the Linux workload environment is sustained – then buy distributed x86- or POWER-based servers to most efficiently execute that workload. If the environment is variable – it is best served by large cache z-based processors.

According to the RFG report, the best workloads to put onto LinuxONE are “applications requiring rapid disaster recovery, business-critical ISV applications, business connectors, data services, development of WebSphere and Java applications, email and collaboration applications, network infrastructure, virtualization and security services, and Web servers and Web application servers.” These types of applications can exploit LinuxONE strengths

The Major Difference Between IBM LinuxONE and x86 Linux Servers

in reliability, availability, processing power, networking and security. But we would also add that the best workloads to put onto a LinuxONE server are those that can take advantage of LinuxONE cache to host more and more virtual machines that can then make variable use of underlying resource pools. These types of applications can be run more efficiently on LinuxONE than on comparatively low cache x86 servers.

In this *Research Report* we barely touched on other important Quality-of-Service differentiators that make LinuxONE servers a better choice for enterprises that must achieve very high service levels. We established that LinuxONE servers can process variable Linux workloads far more efficiently than x86-based servers – but we did not concentrate on other advantages such as industry leading meantime-between-failure (MTBF); the industry's strongest security level (EAL Level 5+); and strengths such as lower total cost of ownership (TCO) and better return-on-investment (ROI). We noted that the RFG report mentioned earlier has done an excellent job covering these differentiators – and we saw no need to duplicate that report. We strongly support every argument put forward in that report.

Get Your Head Out of the Sand

Many IT executives have their heads in the sand when it comes to alternate-to-x86 microprocessor and system designs. These executives need to understand that there are certain workloads best served by x86 servers – and other workloads best served by other types of servers such as LinuxONE.

We strongly believe that it is necessary to understand the differences between these x86 and LinuxONE designs in order to maximize system throughput and efficiency. Executives who put the wrong workloads on x86 architecture could be wasting hundreds of thousand if not millions of dollars on increased licensing costs and increased costs for additional systems and networking equipment.

Clabby Analytics
<http://www.clabbyanalytics.com>
Telephone: 001 (207) 239-1211

© 2016 Clabby Analytics
All rights reserved
October, 2016

Clabby Analytics is an independent technology research and analysis organization. Unlike many other research firms, we advocate certain positions – and encourage our readers to find counter opinions – then balance both points-of-view in order to decide on a course of action. Other research and analysis conducted by Clabby Analytics can be found at: www.ClabbyAnalytics.com.