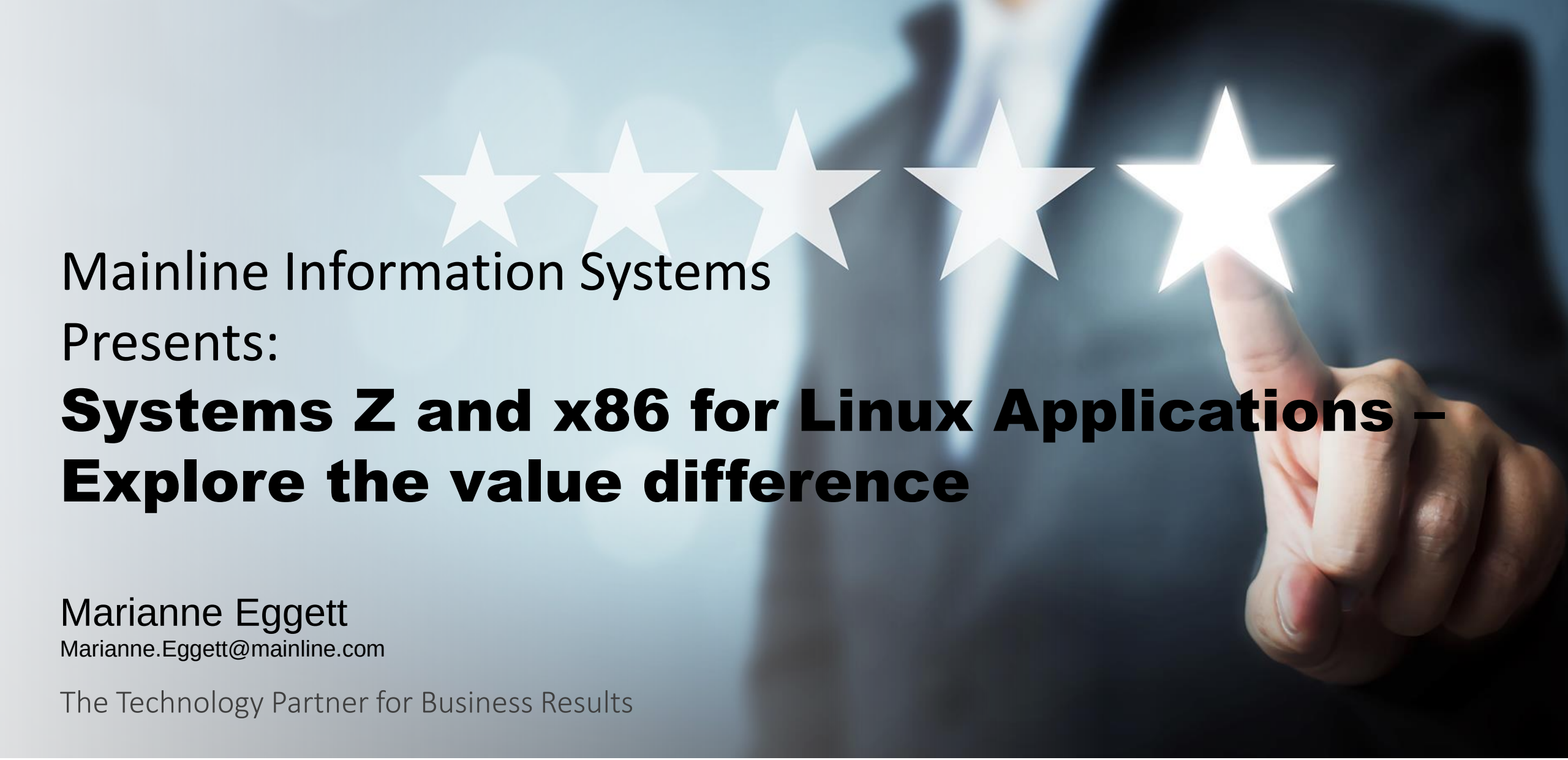

Mainline Information Systems

Presents:

Systems Z and x86 for Linux Applications – Explore the value difference

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The Technology Partner for Business Results

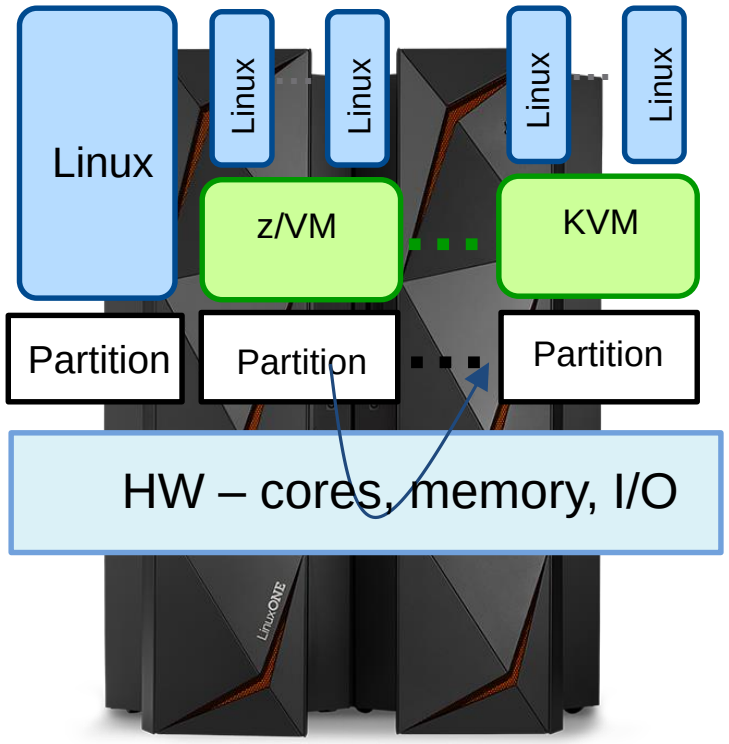
Mainline INFORMATION SYSTEMS

Agenda

- Overview of Linux on IBM Z and LinuxONE Server
- Comparison with x86 alternatives
- Wrap up

Linux on z and LinuxONE Key Facts to remember

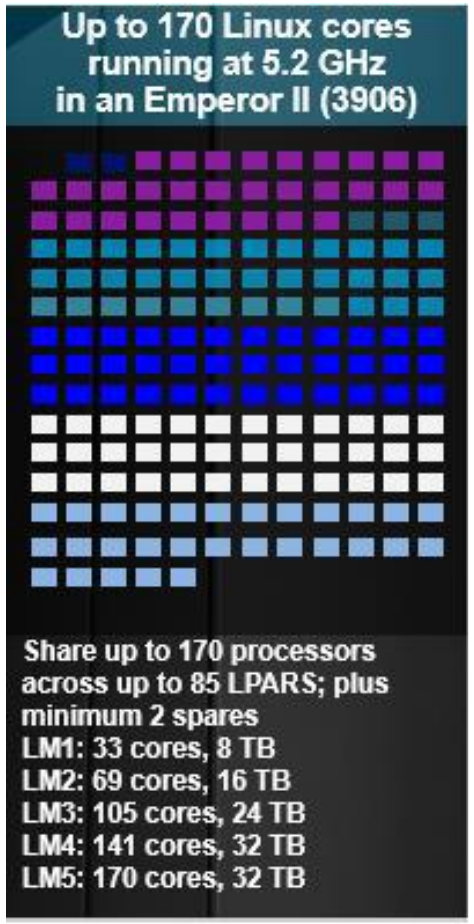
	IBM LinuxONE	Commodity x86 server
Faster Performance	**5.2 GHz** (Emperor II), 4.6 GHz (Rockhopper II)	2.3 GHz (Xeon Gold 6140 – Skylake)
	• Encryption is 2.2 x's faster than Skylake • IFLs 1.9 to 2.8 x's more throughput for database applications • JAVA garbage collection 92% less processing time	
More Secure	*Per core* crypto co-processing	Crypto co-processing shared by all cores
	• LPAR is EAL5+ • Protects to FIPS 140-2 Level 4 certified (tamper proof) • Secure Service Containers has evolved to Hyper Protect appliances	
More Reliable	Mean time to fail is measured in decades	
	• High priority workload receives resource precedence • Idle cores for automatic fail over with no disruption to application • Zero memory failures using RAIM	
Costs Less	Consolidate "priced per core" software	
	• Consolidate 100s to 1000s of x86 cores has huge savings	



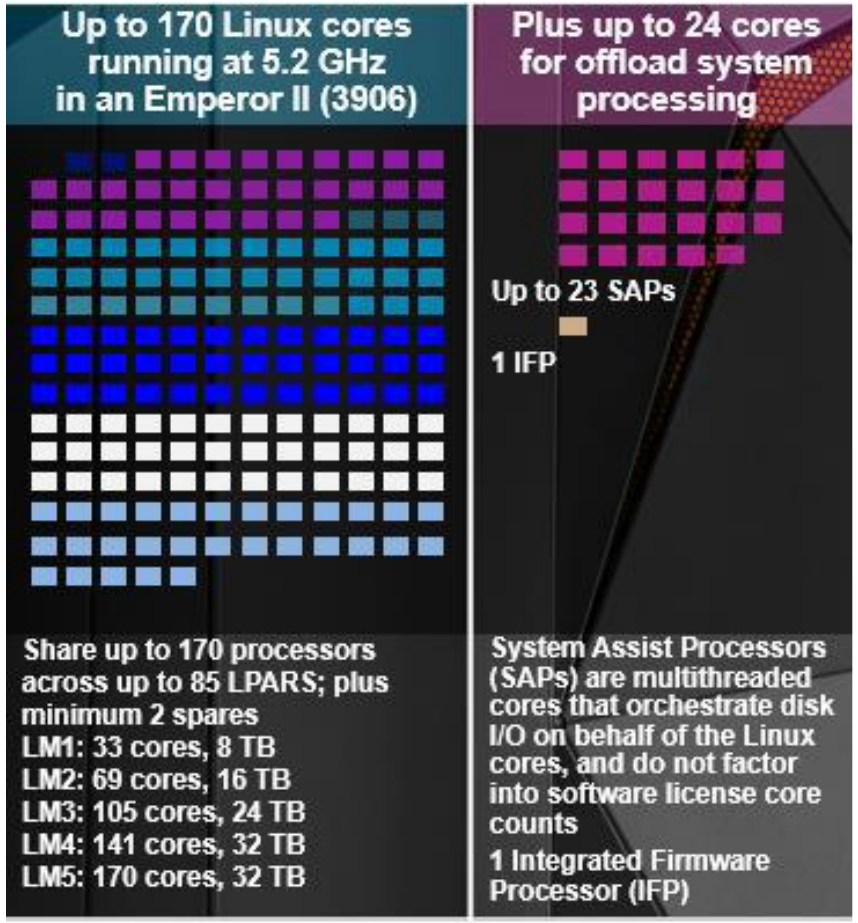
IBM LinuxONE

FASTER PERFORMANCE

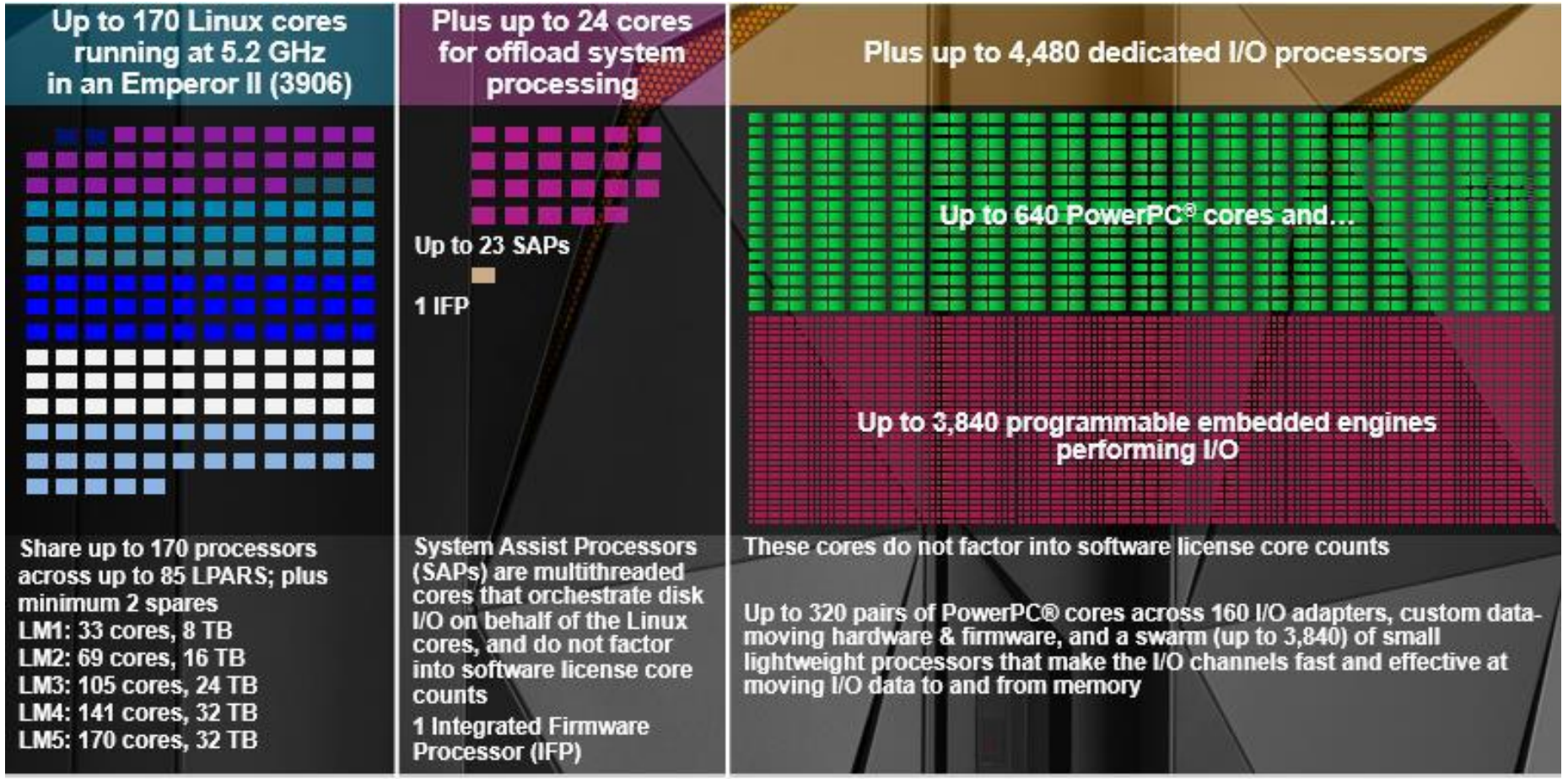
IBM Z Architecture Based Server – Highly Engineered Processor and I/O Infrastructure



IBM Z Architecture Based Server – Highly Engineered Processor and I/O Infrastructure

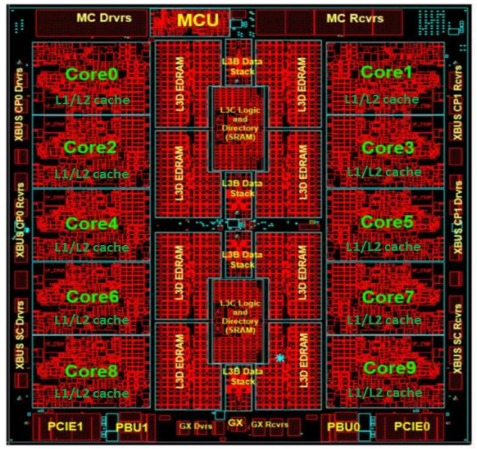


IBM Z Architecture Based Server – Highly Engineered Processor and I/O Infrastructure

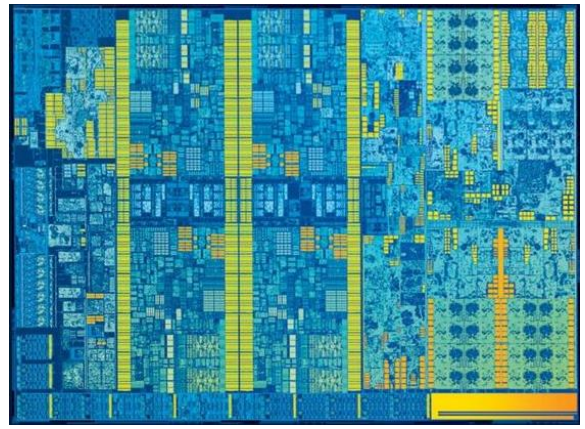


Architectural differences – at the **chip** level

IBM LinuxONE processor chip



14 nm SOI chip technology

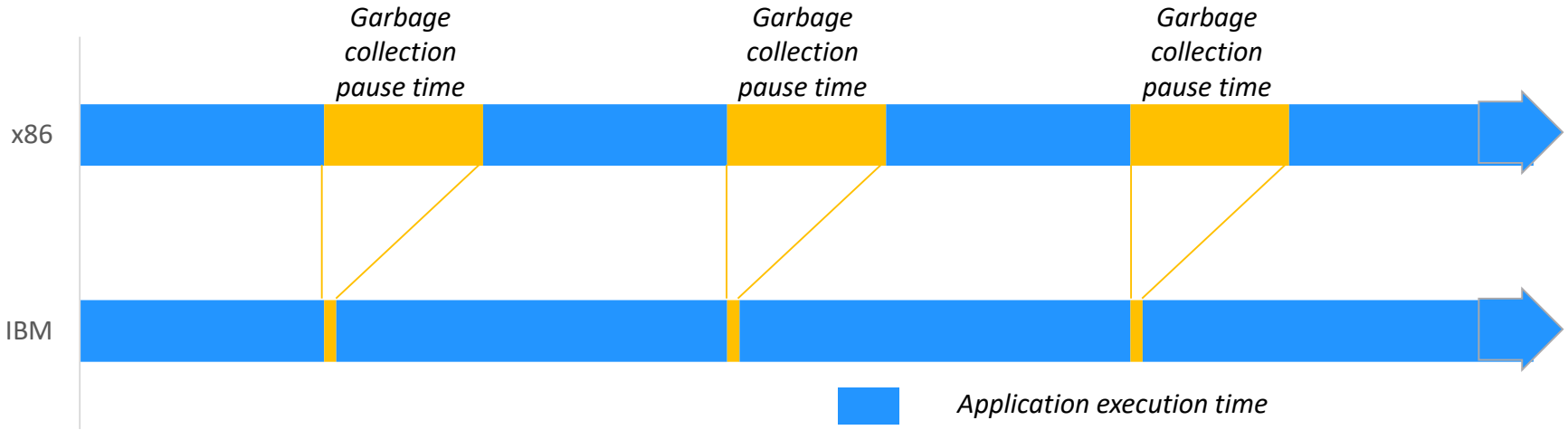


Intel Xeon "Skylake" processor chip

14 nm SOI chip technology

	IBM LinuxONE	Commodity x86 server
Core clock speed	**5.2 GHz** (Emperor II), 4.6 GHz (Rockhopper II)	2.3 GHz (Xeon Gold 6140 – Skylake)
L1 / L2 cache	128 KB I + 128 KB D / 2 MB I + 4 MB D – per core	64 KB / 256 KB per core
L3 cache	128 MB – shared by all active cores on the chip	24.75 MB – shared by all cores on chip
L4 cache	672 MB – on separate chip, shared by all active cores	N/A
SMT, SIMD, OOO, HTM	Yes, yes, yes, yes	Yes, yes, yes, yes
Java enhancements	Pause-less garbage collection	N/A
Cryptographic functions	*Per core* crypto co-processing	Crypto co-processing shared by all cores

IBM LinuxONE can significantly improve service delivery for many Java enterprise applications



IBM LinuxONE garbage collections times were:

- **92%** lower than x86 server (Emperor II)
- **90%** lower than x86 server (Rockhopper II)

IBM LinuxONE Emperor II delivered

3.8x ***More throughput*** at a common response time

92% ***Lower response time*** at a similar throughput rate

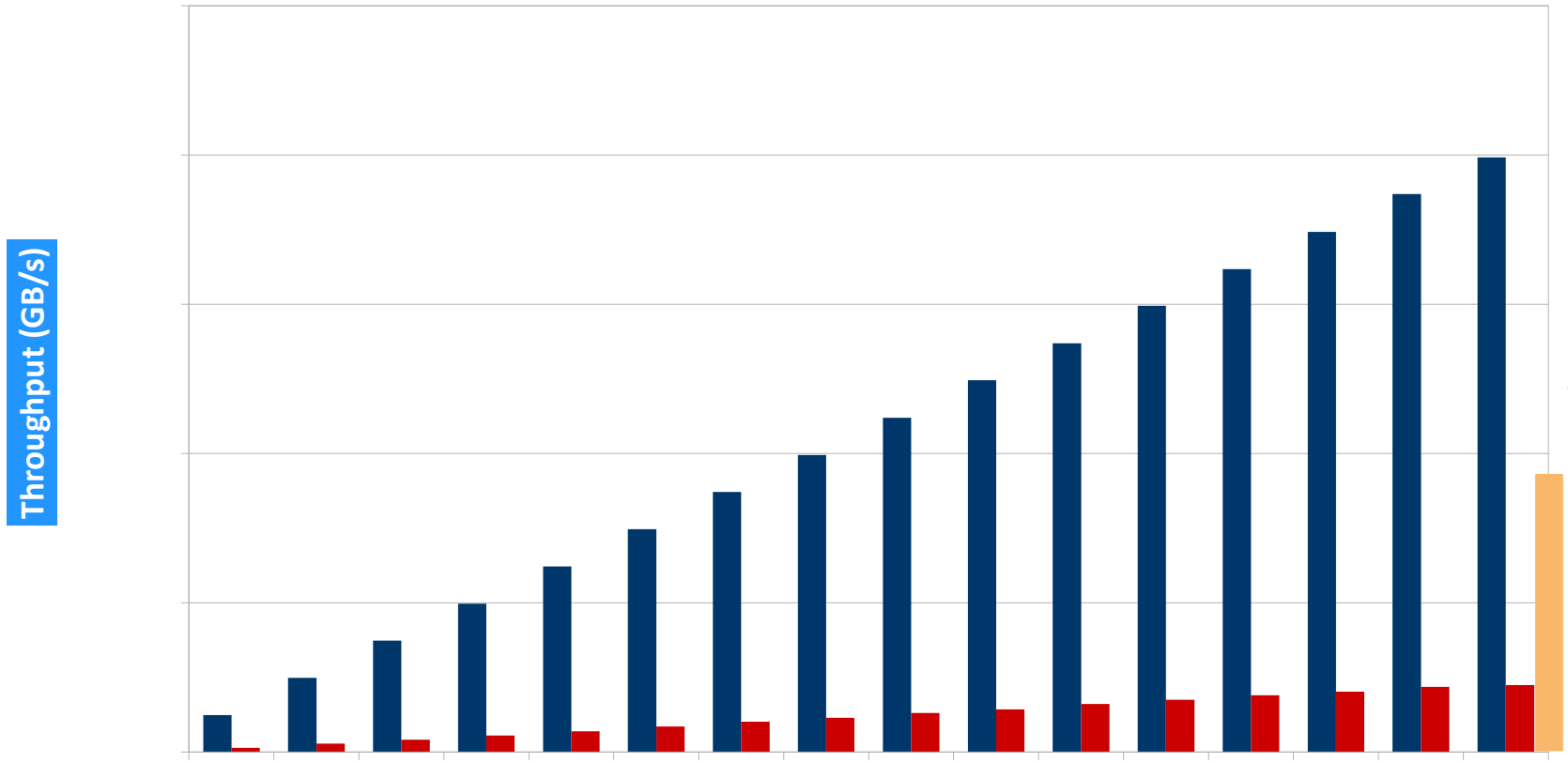
IBM LinuxONE Rockhopper II delivered

3.0x ***More throughput*** at a common response time

80% ***Lower response time*** at a similar throughput rate

Based on an IBM internal study. The x86 server used was a Lenovo SR650 ("Skylake"). Both platforms used 8 Linux cores, RHEL 7.4, and IBM Java 1.8 SR5. The workloads ran "bare metal" (no additional software hypervisor) on both platforms. Guarded Storage Facility was enabled on IBM LinuxONE. Workload used was a large-scale Java transactional workload that simulates a retail business.

Encryption on LinuxONE is dramatically faster than on x86



~9x better

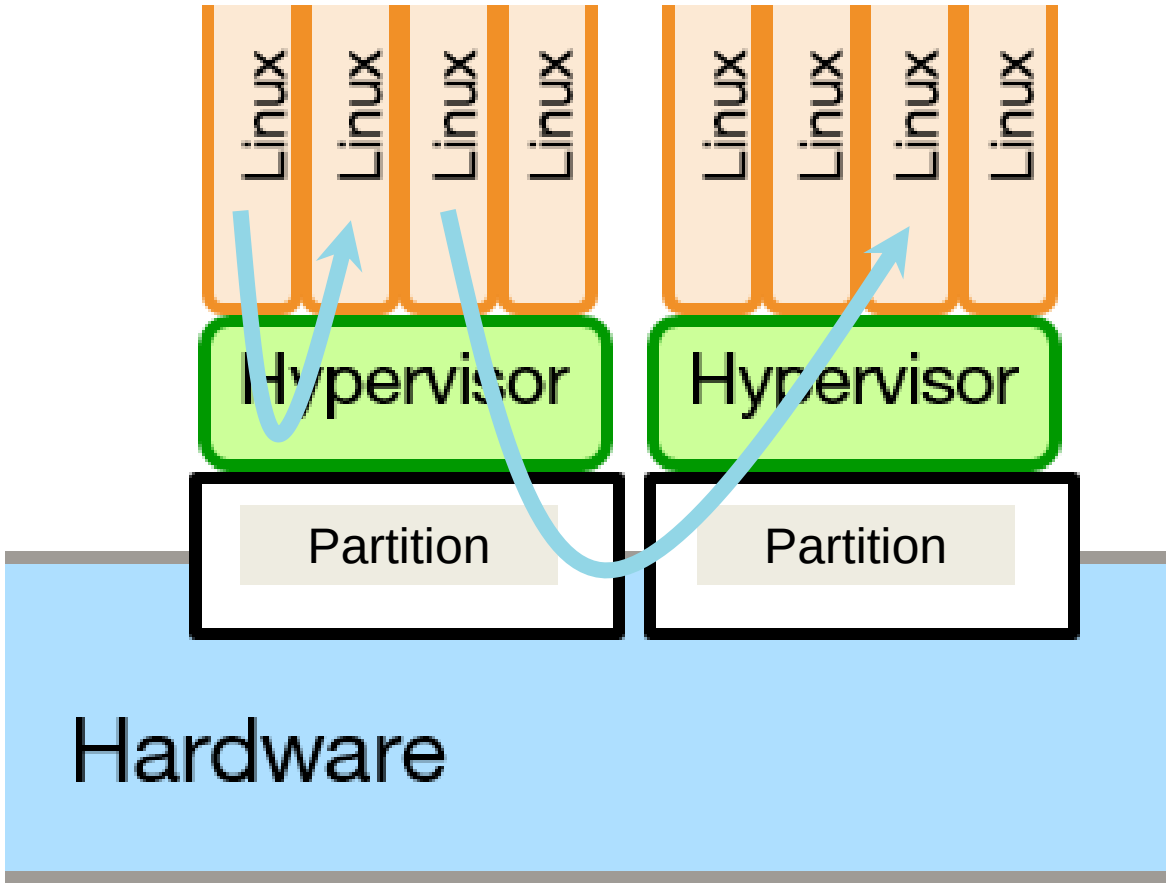
LinuxONE

Skylake delivers improved encryption, but LinuxONE is still 2.2x better

z14 x86

Source: IBM internal study. OpenSSLSpeed Benchmark, AES-256-GCM, 8K Buffer, Broadwell vs. LinuxONE, 16 x cores per LinuxONE cores.
Results my vary.

Fast, internal communications reduces network-induced latency…



… and eliminates the network cabling nightmare

- Within a partition:
  - VMs communicate via virtual network managed by hypervisor
  - No point-to-point physical connection
- Between partitions:
  - VMs communicate over fast partition-to-partition link (Hipersockets)
  - Secure IP communications, but *at memory speed* – *better* than air-gapped commodity servers

LinuxONE Emperor II delivers higher database throughput compared to x86 servers

Test run	LinuxONE throughput exceeds x86 throughput (per core)
DayTrader benchmark on WebSphere Application Server 8.5.5.9 and DB2 LUW 11.1.1.1	1.9x
DayTrader benchmark on Apache TomEE 1.7.1 and MariaDB 10.1.21	2.3x
MicroBM CPU benchmark on InfoSphere DataStage 11.5	2.8x
Acme Air benchmark on Node.js 6.10 and MongoDB 3.4.2	2.5x
pgBench benchmark on PostgreSQL 9.6.1	2.0x
YCSB benchmark on MongoDB 3.4.1	2.6x

*With LinuxONE, run **multiple database servers** and data types on the same system, delivering **more work** with one system than x86-based data serving platform*

All claims noted on this slide are based on IBM Internal measurements. Results may vary. Additional information is available upon request

MORE SECURE

Applications and data are safer on LinuxONE than on x86 servers

IBM LinuxONE

- *Every core* has its own embedded co-processor for cryptographic functions (CPACF)
- CPACF is not optional; it's just there; turn it on with a feature number
- Encryption throughout is *3-9x faster* than x86
- Hardware Security Module (HSM) – Crypto Express6S – is tightly integrated with CPACF, enabling unique *"protected key"*
- Protects to FIPS 140-2, Level 4 – *tamper proof*
- Logical partitions are rated by Common Criteria as *EAL 5+ isolation. IBM Z/VM is EAL 4+.*

x86 servers

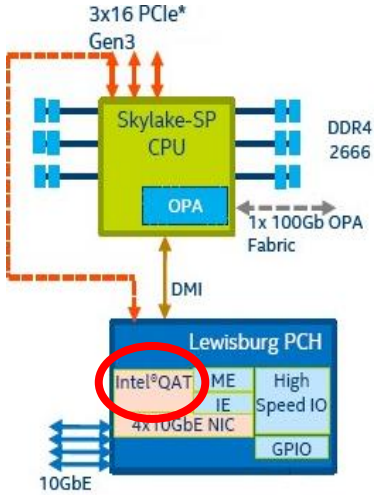
- Cryptographic co-processor *off die and shared* across all cores
- Crypto has to be specifically requested; it's not obvious if it's there or not
- AES-NI does not perform as well
- Available HSMs are not as integrated; protected keys are not the ones for data at rest and data in flight
- Typically protects only to FIPS 140-2, Level 3
- VMware is only EAL 4+, potentially leading to "noisy neighbor" or bleed-through effects

Just ordering an Intel server optimized for cryptography is a challenge

Introduced with **Westmere**

Instructions assist, but do not fully implement, **AES encryption**

Not available in all CPU versions until **Skylake**



Introduced with **Skylake**, the **Platform Controller Hub (PCH)** includes **Quick Assist Technology**(QAT), which *does* implement AES

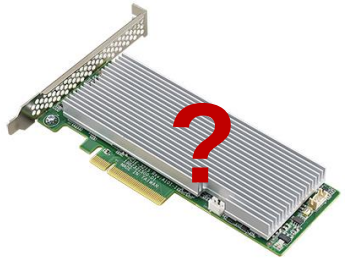
But the PCH is an off-die co-processor, and shared by all cores

C628
C627
C626
C625
C624
C622
C621

Of the 7 versions of the **PCH**, only 4 support **QAT**

QAT is a mutually exclusive feature

QAT is only available on desktops and small servers



QAT is also available on an add-on card, but performance is not much better than AES-NI on Skylake processors

Adding on a card may not be an option for some systems

LinuxONE has a clear advantage over x86 when it comes to security

- *Securing commodity Linux servers to the level of IBM LinuxONE is simply not possible…*

	LinuxONE security	DIY x86	x86 with bolt-on transparent encryption
Hardware Security Module (HSM)	●	◑	◕
Cryptographic acceleration	●	◑	
Protected key	●	○	
File encryption	●	◔	◑
Real-time audit	●	○	◕
Network traffic encryption	●	◔	◔
Server cluster traffic encryption	●	◔	◔
Secure service containers	●	○	◑

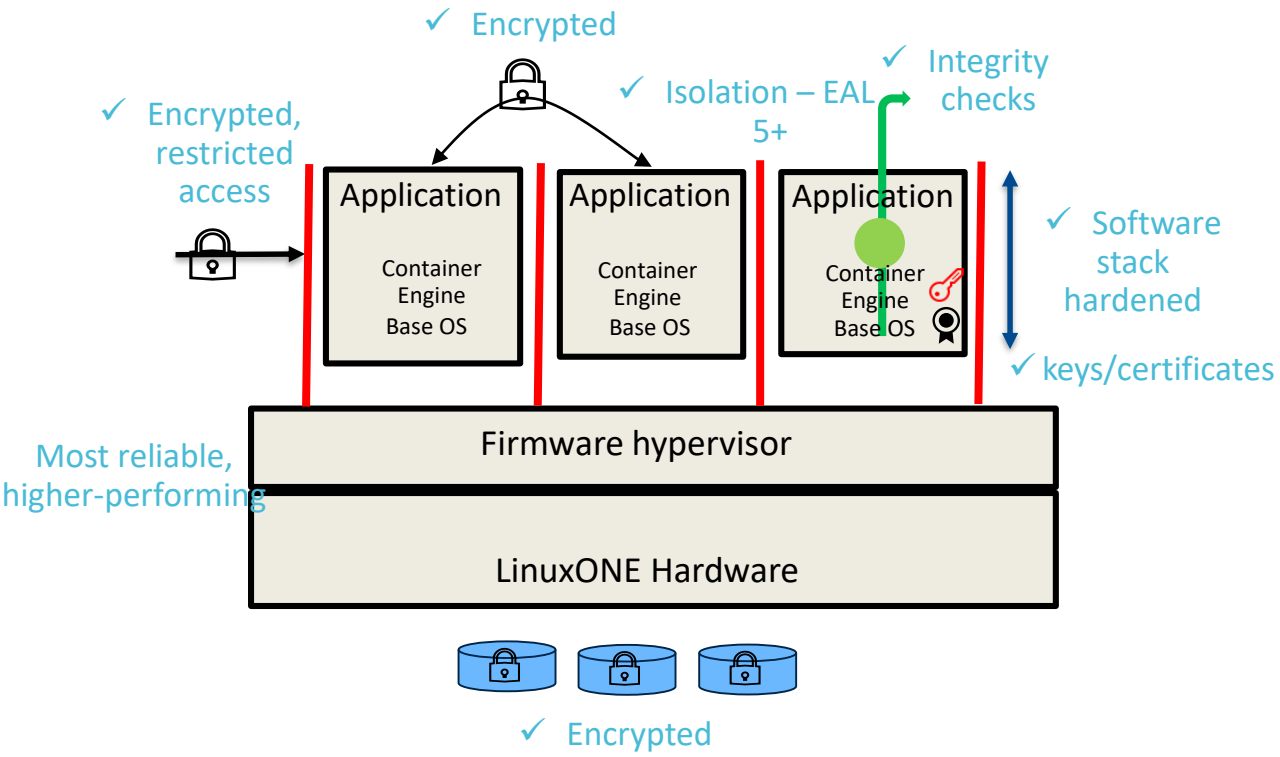
YouTube Video

- Hear in this 5-minute video of IBM's unique implementation of Pervasive Encryption for your data volumes

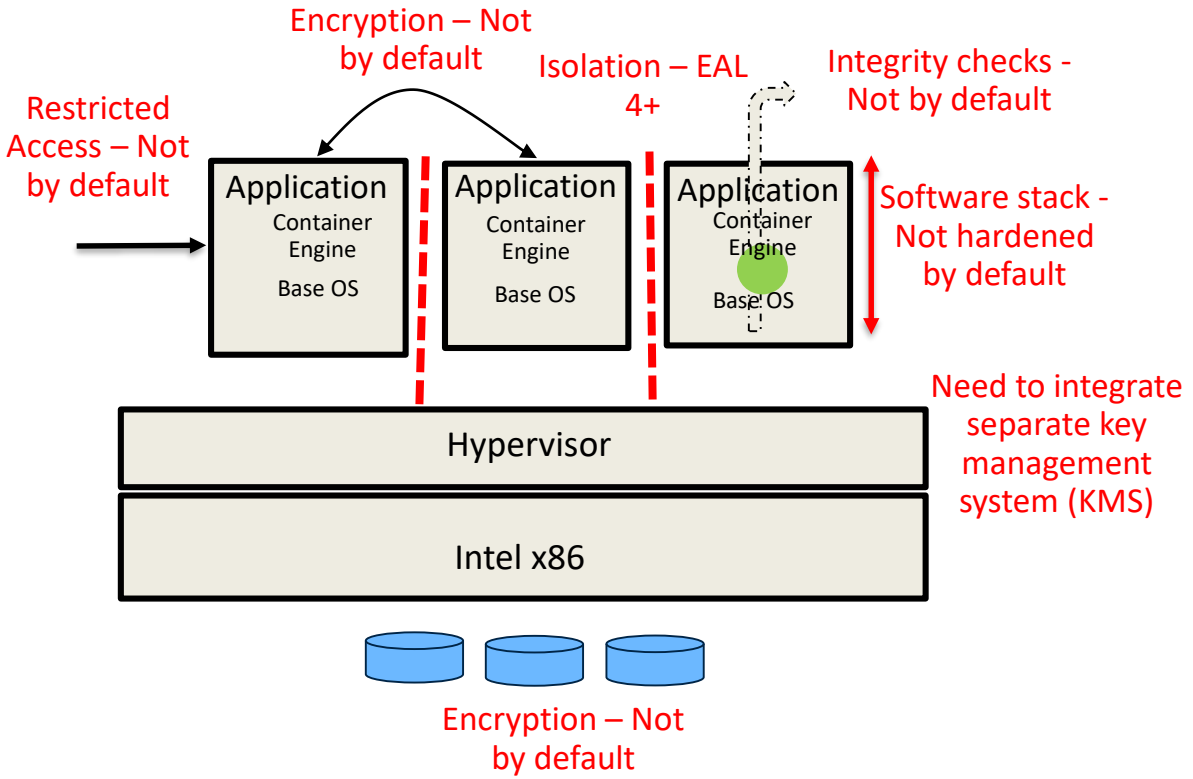
- https://www.youtube.com/watch?v=jDK3ZwEdX4I

LinuxONE with Secure Service Containers is better than x86 alternative

IBM LinuxONE with Secure Service Containers



x86 with DIY security



Source: IBM analysis as of 10/10/2018

IBM Cloud Hyper Protect Services

Hyper Protect Crypto Services	Hyper Protect DBaas	Hyper Protect Virtual Servers	Hyper Protect Containers
Keep your own keys for data encryption protected by dedicated cloud HSM*	**Complete data confidentiality for your sensitive data**	**Create Linux VMs with own public ssh key to maintain exclusive access to code and data**	**Build and deploy micro services within a hyper secure environment**
* Industry's only FIPS 140-2 Level 4 certified HSM	(PostgreSQL, MongoDB EE)	(Ubuntu)	(Kubernetes)
GA 1Q19	Beta 1Q/GA 2Q19	Experimental in 1Q19	Coming soon

Only you have access to your data, encryption keys and workloads. Only your cloud admin has access!

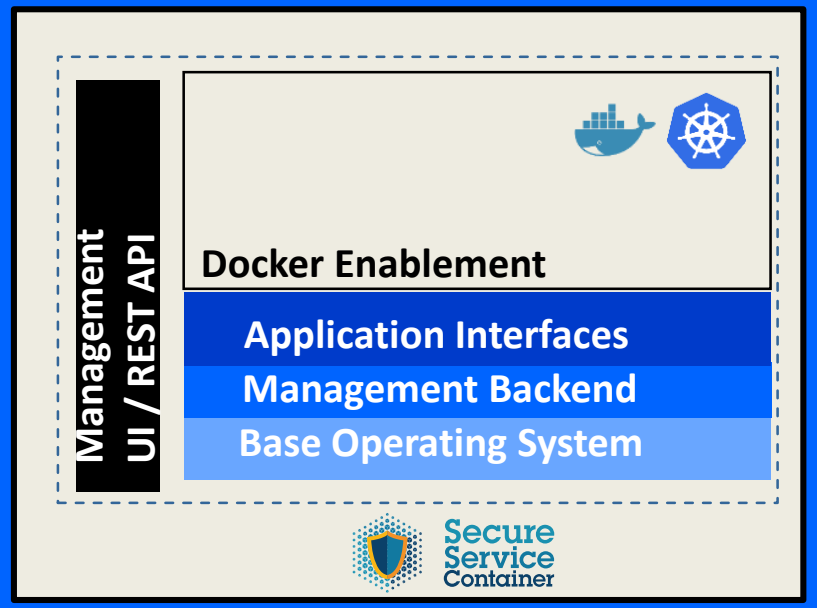
- Secure Service Containers are the future for LinuxONE workloads

EAL 5+ isolation

Up to 16 TB Memory

- No host- or OS-level interaction
- Administrator is not trusted – cannot access processor or memory state
- Access only to legitimate users through narrowly scoped interfaces
- Data encrypted in flight and at rest
- Signed or encrypted, with verified boot components

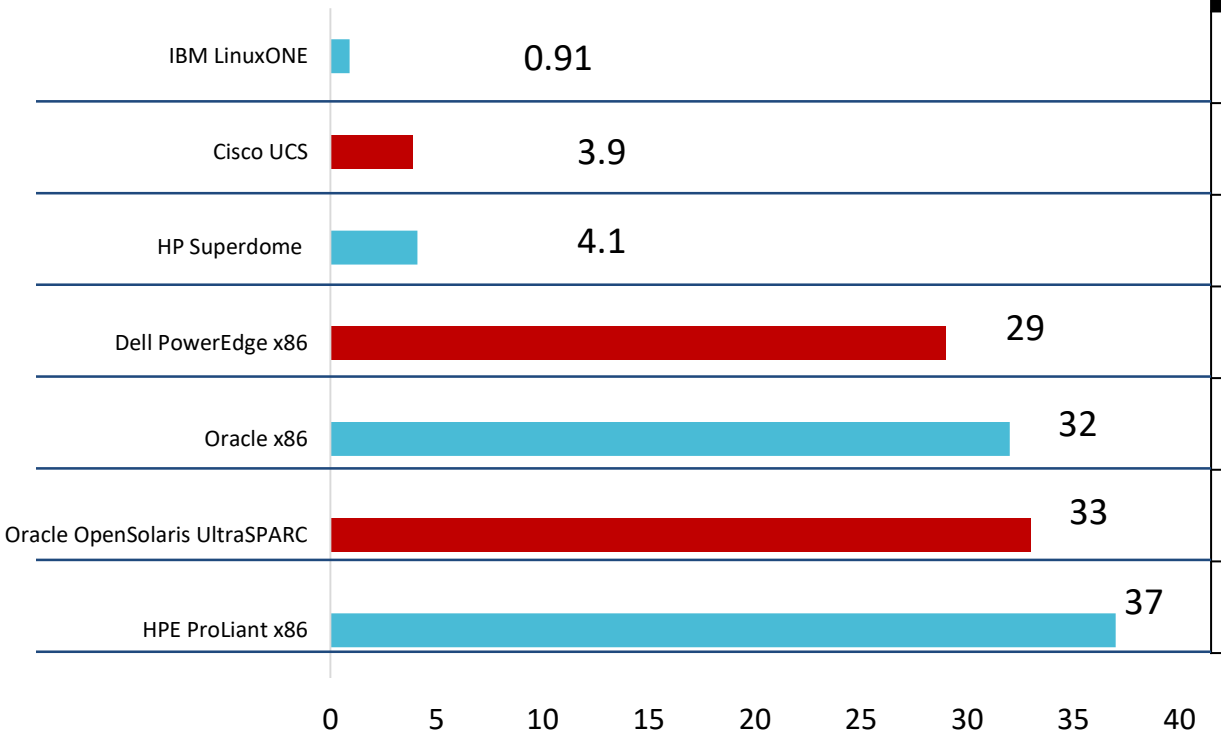
x86 servers do not have a comparable feature



MORE RELIABLE

IBM LinuxONE delivers the highest availability

From ITIC: Unplanned downtime per server, per year (in minutes) in 2017-2018 (Linux servers)



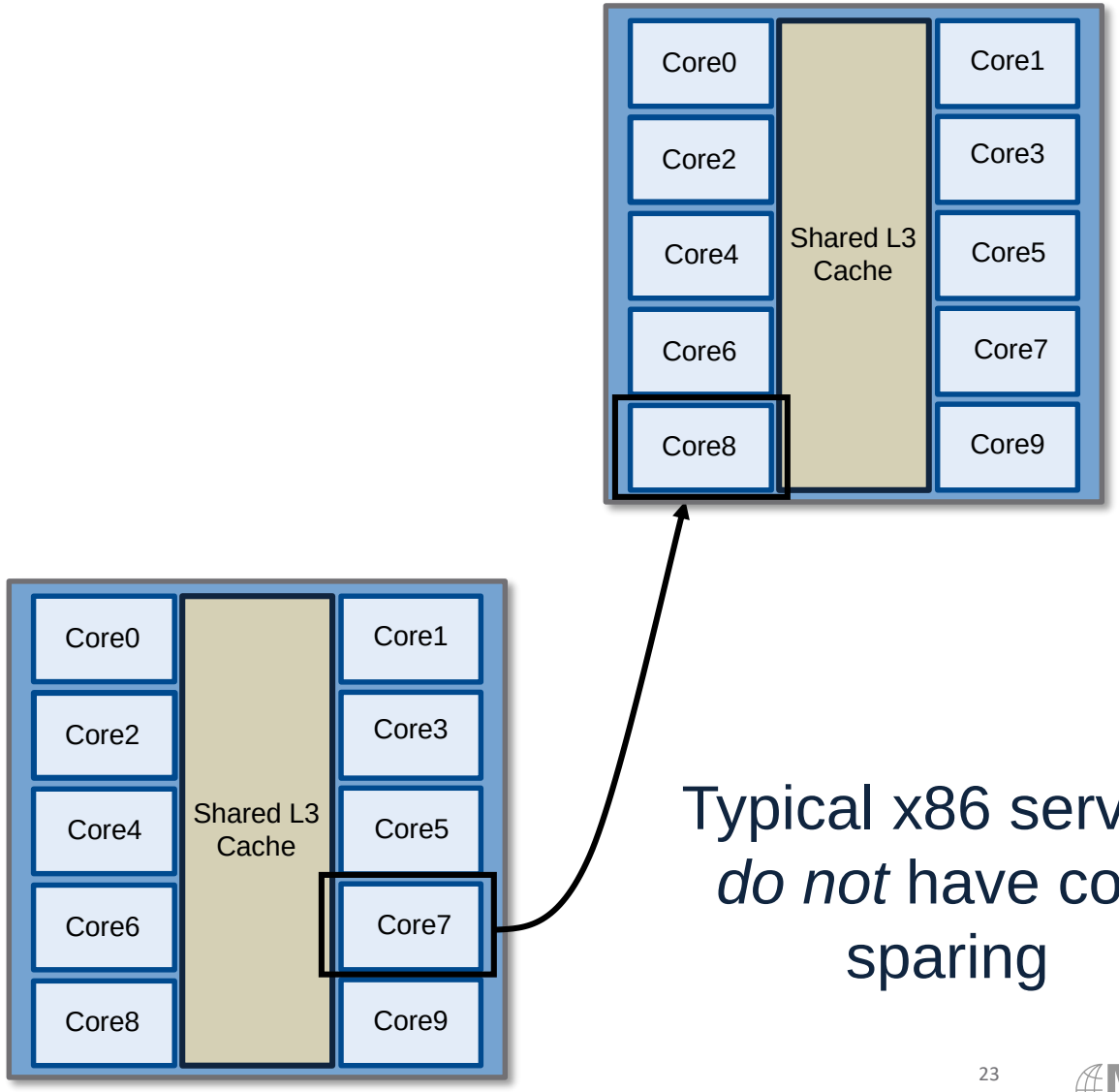
% availability equivalent
99.99983
99.99926
99.99922
99.99449
99.99392
99.99373
99.99300

- IBM LinuxONE exhibits **true fault tolerance**
- Close to 6 9's availability – far better than traditional x86 servers, and better than converged systems
- For IBM LinuxONE, the mean time between failures is measured in *decades*, not months

Source: ITIC 2017-2018 Global Server Hardware, Server OS Reliability Survey. ITIC surveys are independent, and receive no vendor sponsorship.

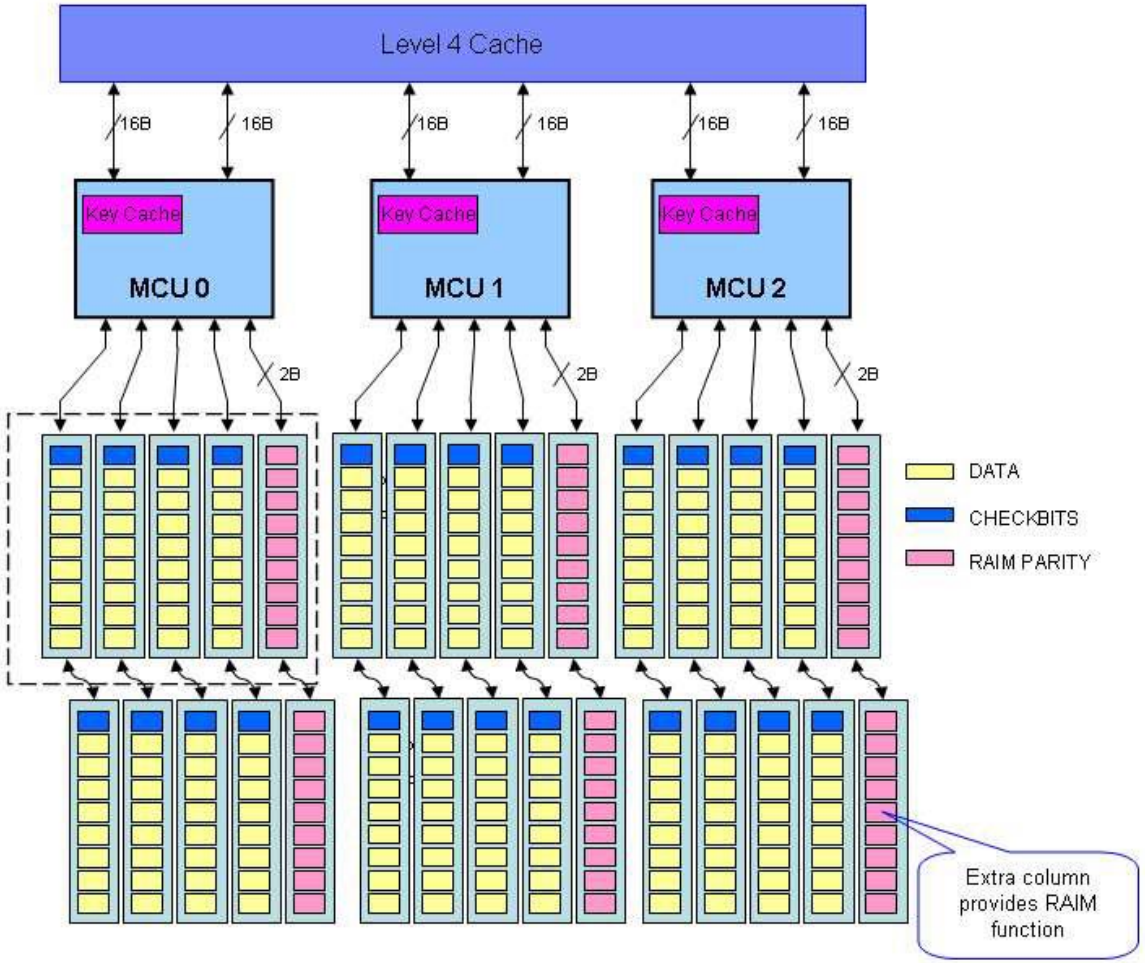
If a core fails, a spare can be "turned on" without system or program interruption

- Most LinuxONE servers ship with two extra cores designated as spares
  - In addition, any unused core can act as a spare
- Core failover (called sparing) is transparent to applications
- Spares need not be local on the same chip or in the same drawer
- Any core can failover to a spare



Typical x86 servers *do not* have core sparing

LinuxONE systems never go down because of memory failures

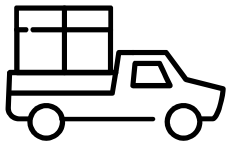


- LinuxONE uses special memory that is designed to eliminate even the most remote failures (due to cosmic radiation)
  - Redundant Array of Independent Memory (RAIM)
  - Very robust , very cost effective
  - No performance penalty
  - Covers memory buses, DIMM connectors, clock failures, etc.
- Zero observable memory failures on systems using RAIM

A level of memory protection not found on typical servers

COST LESS

Architectural differences – at the **box** level

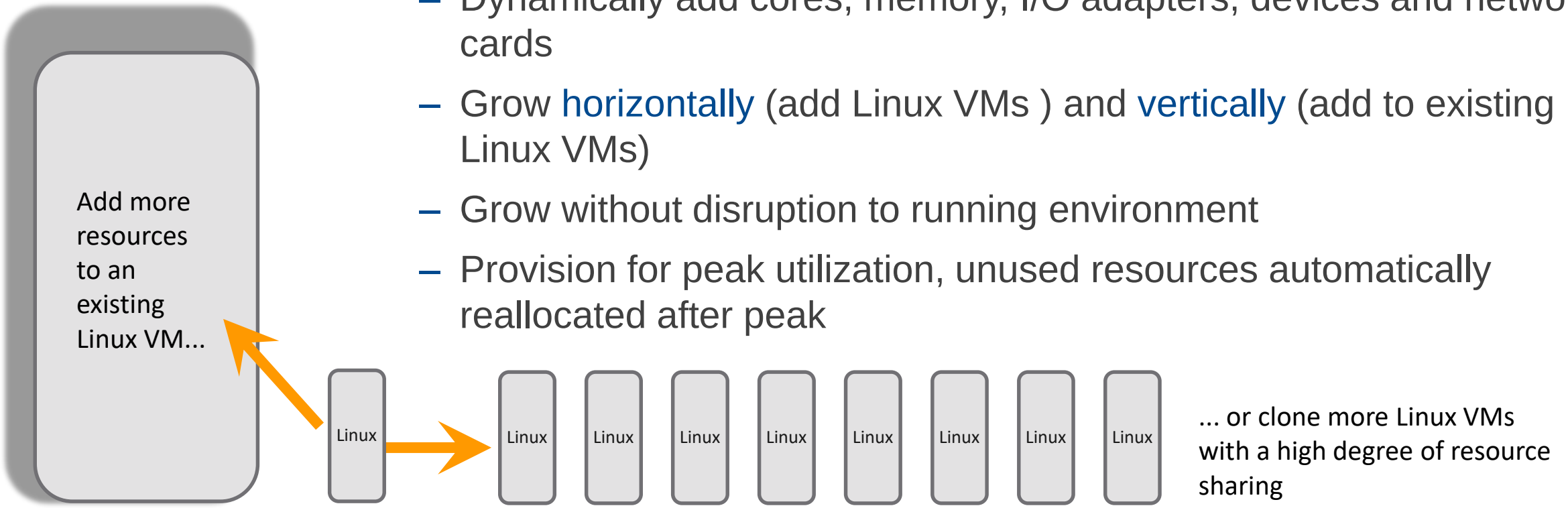


	Total capacity (GHz)	Total memory	Number of server "equivalents"
LinuxONE	Up to 170 cores @ 5.2 GHz = 884 GHz	Up to 32 TB total, or 16 TB per logical partition	Up to 85 logical partitions, each supporting hundreds of VMs
	10-17x more GHz capacity	**21-42x more memory**	**85 : 1**
Typical x86 server	2 sockets 8-18 cores per socket 2.3-3.2 GHz Total = ~51-83 GHz	766 GB	1 server…

LinuxONE is a large, centralized server intended to replace scores of x86 servers…

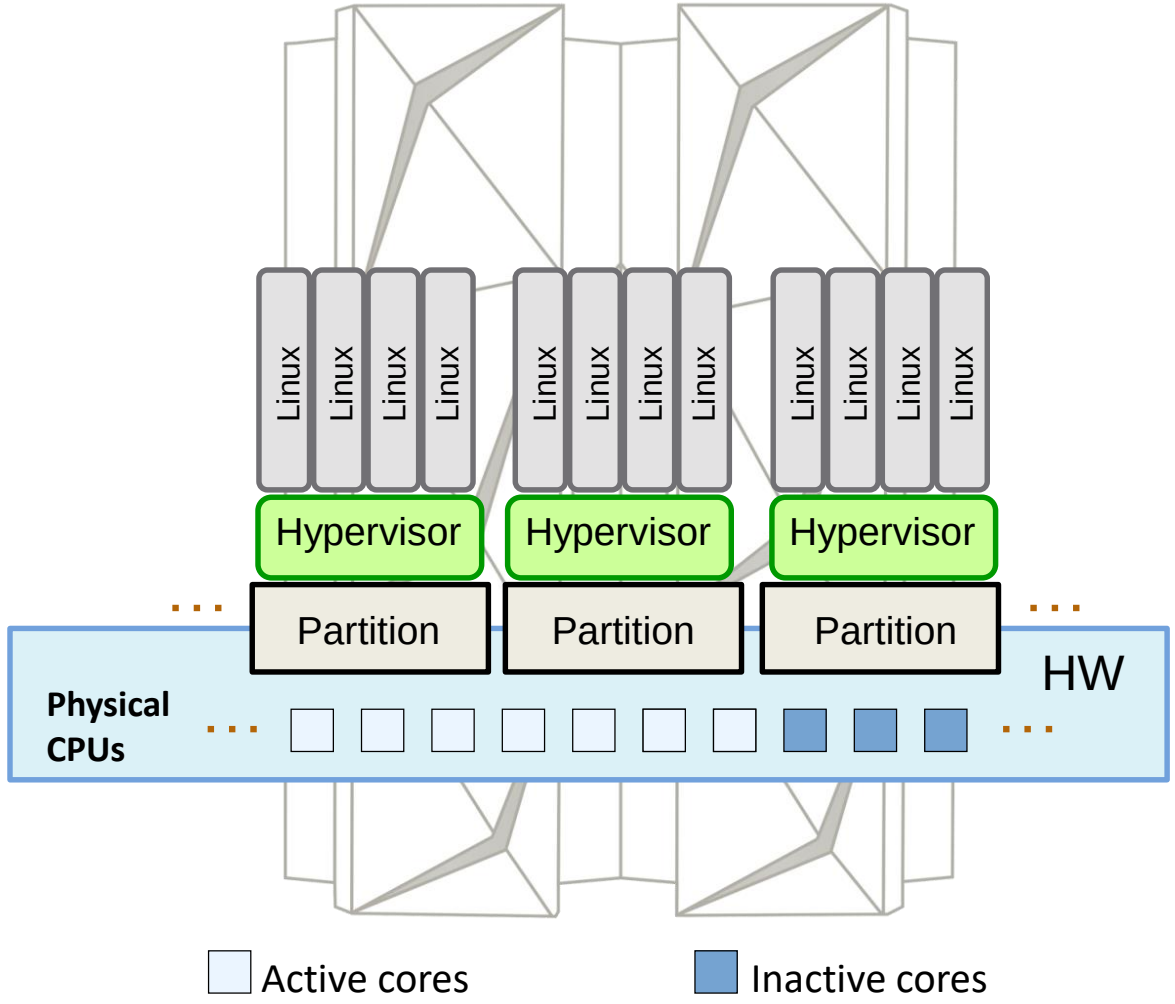
Allocate or share resources across all applications for increased flexibility

- "Shared everything" hardware design means resources can be shared or dedicated to different VMs
  - Dynamically add cores, memory, I/O adapters, devices and network cards
  - Grow horizontally (add Linux VMs) and vertically (add to existing Linux VMs)
  - Grow without disruption to running environment
  - Provision for peak utilization, unused resources automatically reallocated after peak



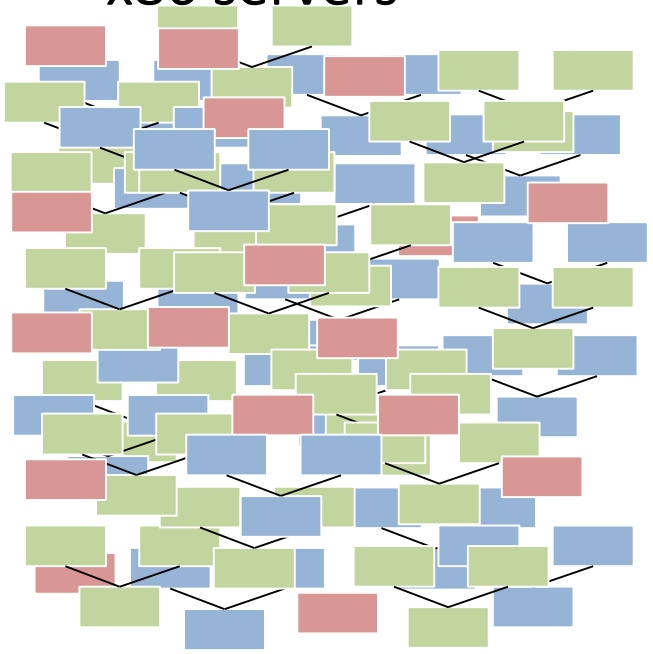
Maintain system availability
even as resources are added or reallocated

- All boxes ship with all cores
  - Activate only the number of cores needed
- As demand increases, activate additional cores
  - Reallocate cores across VMs and across partitions as business and application needs change
- Optionally, activate cores temporarily and pay only for "on" time (Capacity on Demand)
  - Example: Sales cycles may demand extra capacity during specific periods



IBM LinuxONE delivers a cost advantage over x86 servers

Commodity x86 servers



IT Economics sizing tools show:

- Fewer resources (cores) needed to run the same workloads
- Resulting in drastically lower costs

- Large, centralized servers with more resources make more effective platforms, yielding **lower cost per workload** and **lower total cost of ownership**

IBM LinuxONE portfolio - siblings with footprint & scale differences

IBM LinuxONE Rockhopper II

- Equivalent to ~200 x86 cores
- Up to 8 TB memory
- I/O support for up to 2 million IOPS
- 19” industry standard form factor
- PDU-based[1] with 200v to 240v power
- Optional 16U of available frame space for additional components, e.g., storage, server, network switch
- Air-cooled only

IBM LinuxONE Emperor II

- Equivalent to ~1300x86 cores
- Up to 32 TB memory
- I/O requirements up to 9 million IOPS, raw I/O bandwidth of 832 GB/S
- Massive Capacity Back Up (CBU) on demand
- Need for on-site disaster recovery
- Bulk power based on 480v
- Option for water cooling

BIG THROUGHPUT IN A SMALL FOOTPRINT

EXTREME SCALE

Comparison with x86 alternatives

Consolidate Oracle Databases on LinuxONE Emperor II at a lower cost than x86

Which platform can achieve the lowest cost?

Brokerage Database Workloads

49 Brokerage Database Workloads
each with 64 GB memory driving
200 GB database
Average 168 TPS per workload

5 x86 systems
(each system with 44 cores/768 GB)
Oracle VM & Oracle Linux
Oracle 12*c*

220 cores

$5.46M (3yr TCA)
$663/TPS

IBM LinuxONE Emperor II
(LM1/M01 with 33 cores/3392 GB)
z/VM & RHEL
Oracle 12*c*

33 cores

$3.08M (3yr TCA)
$374/TPS

44% lower cost
Estimated for systems compared

This is an IBM internal study designed to replicate a typical IBM customer workload usage in the marketplace. It consists of IBM LinuxONE Emperor II with 33 cores, 3392 GB memory, z/VM, RHEL, Oracle 12c compared to a comparably tuned x86 configuration with total of five x86 systems each with 44 Intel E5-2699 v4 cores, 768 GB memory, Oracle VM, Oracle Linux and Oracle 12c executing a materially identical brokerage database workload in a controlled laboratory environment. Tests for IBM LinuxONE Emperor II measured number of database workloads, each running as a guest on z/VM in a logical partition, executing identical SQL query transaction mix at an average throughput of 168 transactions per second. For the x86 configuration, test measured number of database workloads, each running as a guest on Oracle VM and executing identical SQL query transaction mix at an average throughput of 168 per second. The results were obtained under laboratory conditions, not in an actual customer environment. IBM's internal workload studies are not benchmark applications. Prices, where applicable, are based on US prices as of 09/01/2017 for both IBM LinuxONE Emperor II and x86 environment. Price comparison based on a 3YR Total Cost of Acquisition (TCA) includes all HW, SW and 3 years of service & support which is then divided by the number of average TPS, which results in $ per TPS.

How Sizings Effects the TCO?

Comparative 5-Year Costs Between IBM System z 14 and Distributed CISCO Servers

Cisco

- 43 physical servers
- 324 WebSphere virtual servers
  - 146 Production
  - 103 QA
  - 71 Development
  - 5 Lab
- 765 cores

Z14 LinuxONE w/SMT

Size for concurrent peak of virt servers

- 10% concurrent peak = 33 x86 servers
- 20% concurrent peak = 65 x86 servers
- 40% concurrent peak = 130 x86 servers

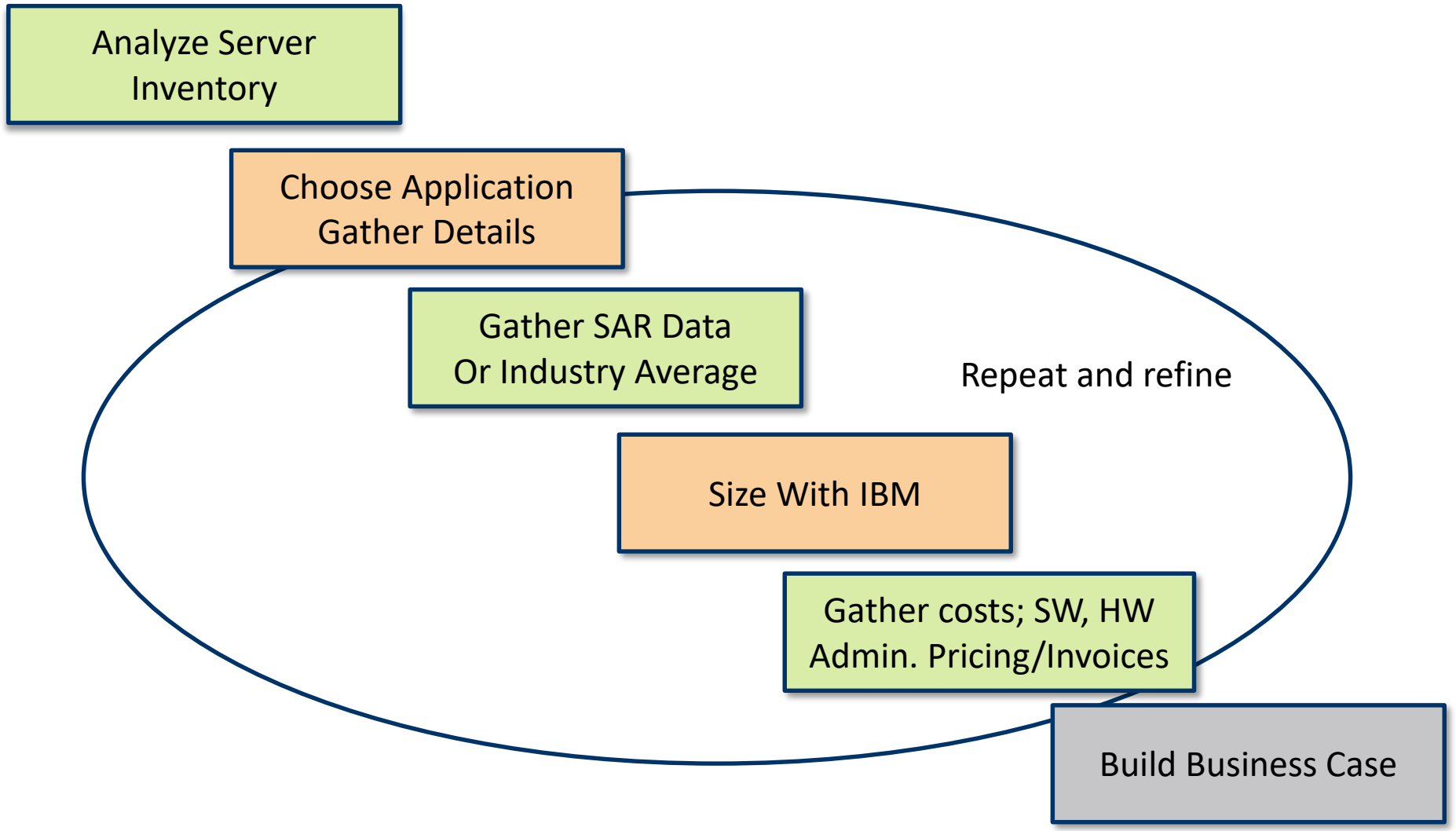
Z13 Emperor $3.8 Million Savings

NOTE: Customer estimated CISCO Utilization. Distributed costs do not included HW refresh and HW maintenance. Z14 sizing assumes SMT 20% boost.

X86 Consolidations to IFLs and "IFL to x86 core ratios": What to Expect from Different Technologies

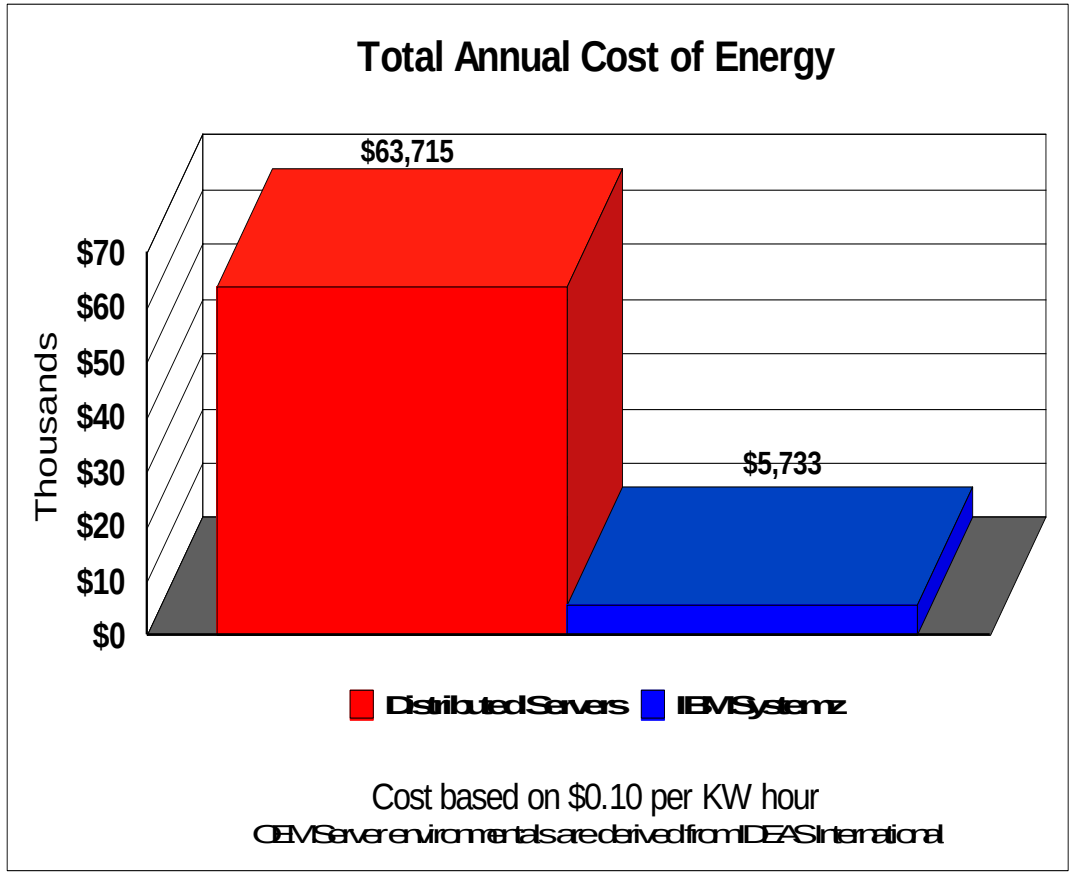
- **Consolidation ratios vary from 1:10 to 1:100, a 10X difference**
- **Average consolidations are generally between 1:12 and 1:25 for current generations of hardware in well managed environments**
- **Why so many less IFLs than x86 cores?**
  - Linux on z shares resources so fewer "bottlenecks" or less processor, memory or I/O contention. Resources are managed by z/VM at machine speeds.
  - Ability to run at 80 to 99% average utilization rates compared to 10% to 45% average utilization for Intel
  - IFLs share resources for workloads 24 x 7 (non concurrent peaks)
  - IFL commonly share environments (prod, dev., test, QA)

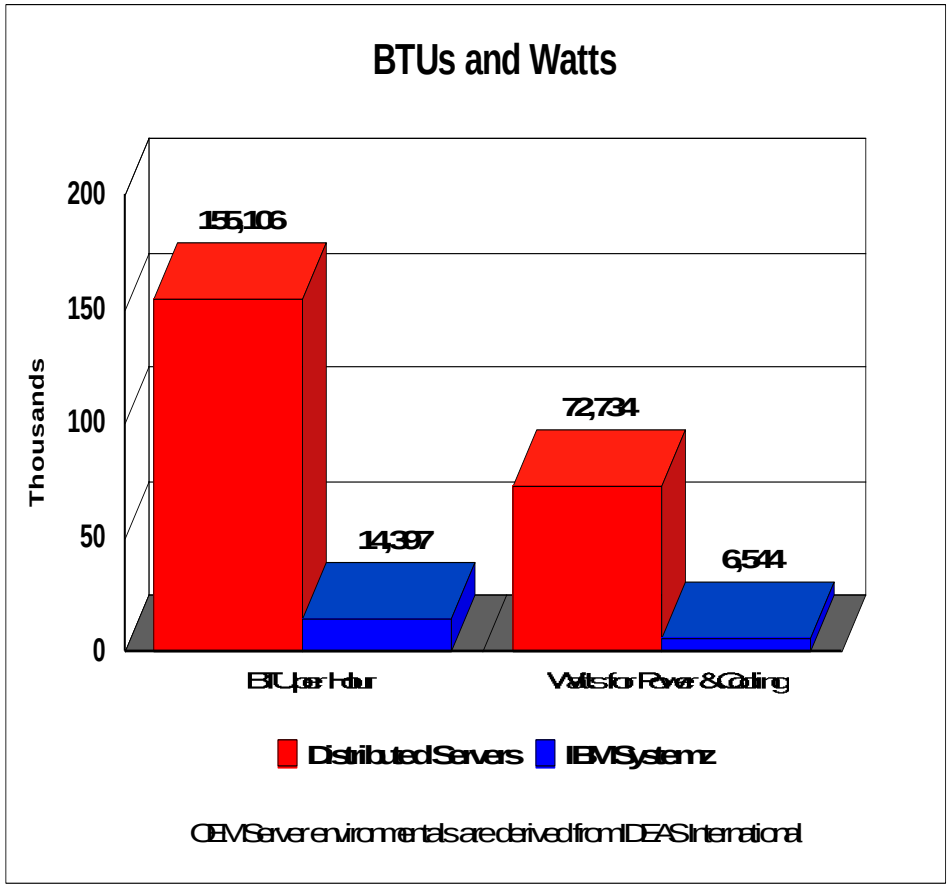
Steps To Build the Business Case



Mainline Information Systems System z Linux Business Case Methodology

Energy Savings





Labor Cost Comparison Between for Oracle x86 servers and Linux on IBM Z

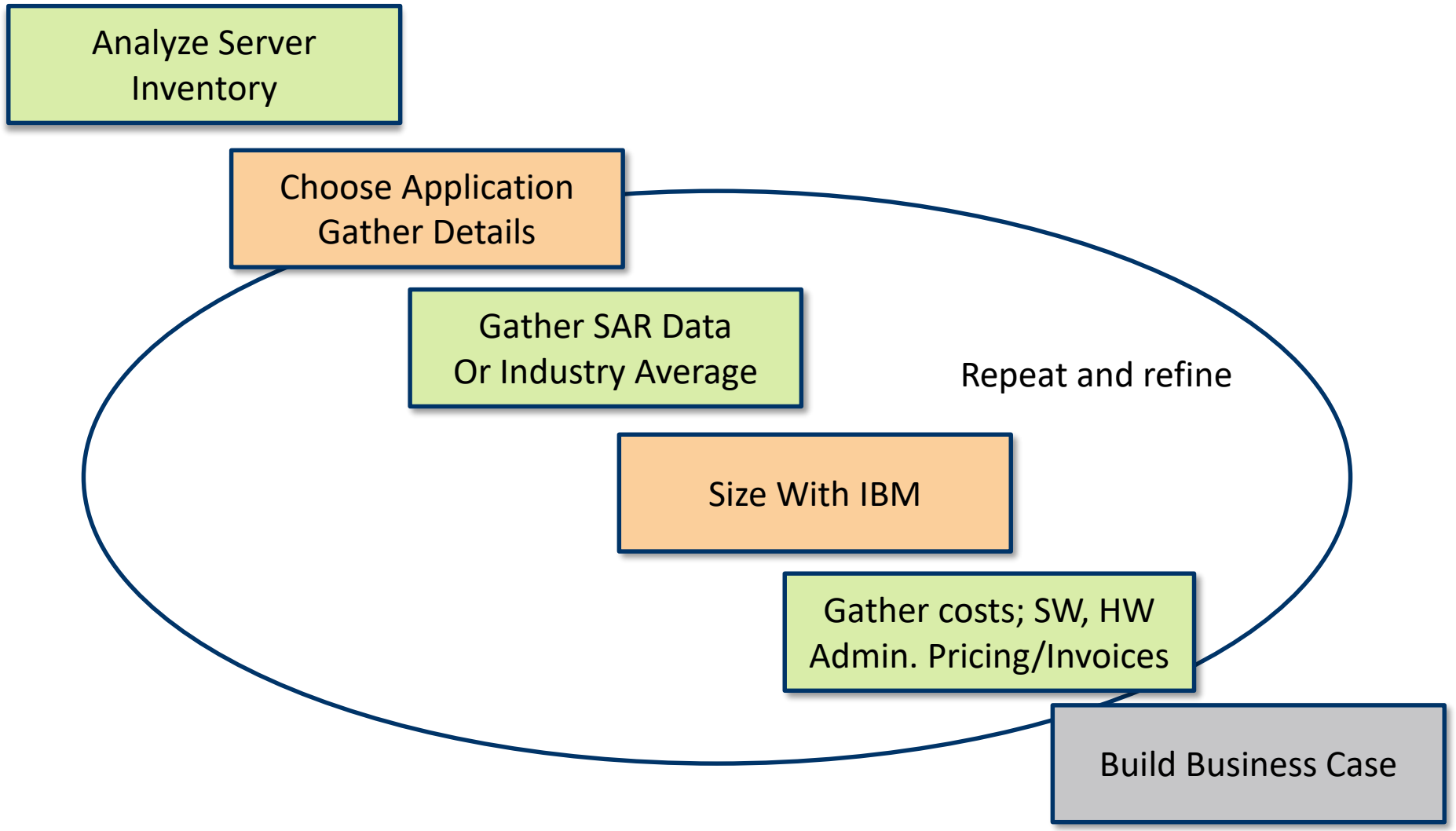
Additional Savings, not included in Business Case

	Window Servers	Linux Servers	TOTAL Intel Servers	System z Linux Servers	Savings
Annual Hours	77,137	12,236	89,374	27,204	62,170
Annual Labor Cost	$984,734	$156,211	$1,140,945	$347,281	$793,664
5-Yr Labor Costs	$4,923,670	$781,053	$5,704,723	$1,736,406	**$3,968,317**

* Annual Fully Burdened cost per FTE is $120,000.

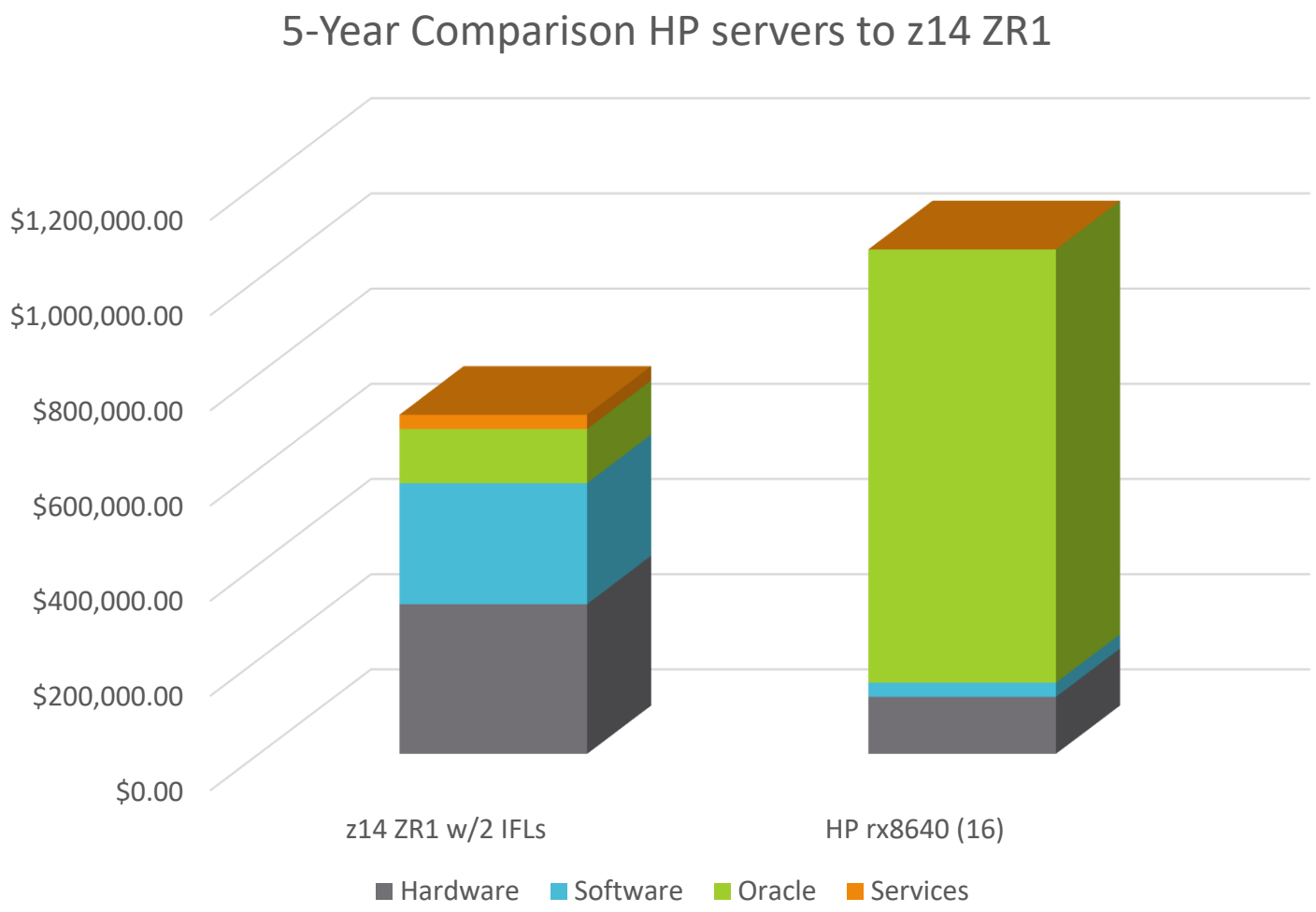
5-Year savings $3,968,317

Steps To Build the Business Case



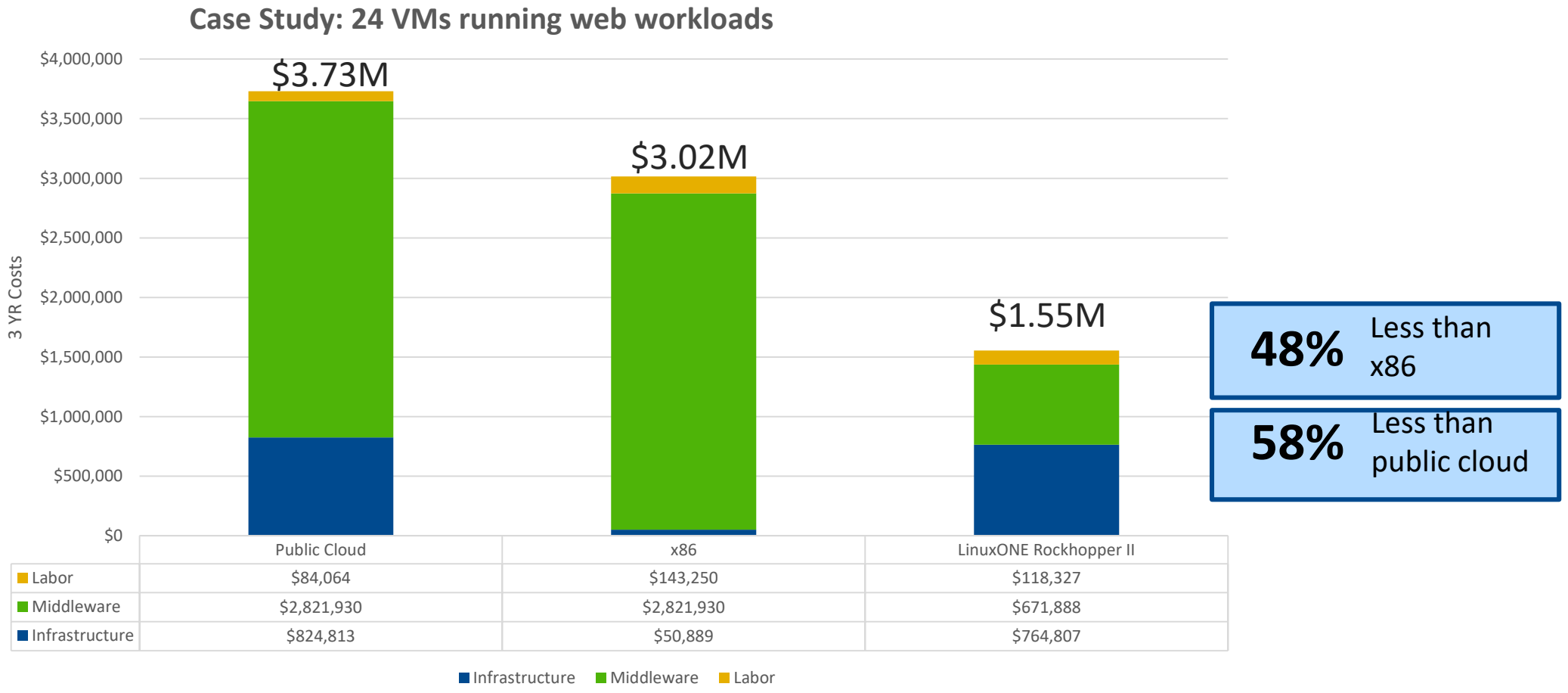
Mainline Information Systems System z Linux Business Case Methodology

Comparing a Smaller Oracle Workload TCO



- z/OS and Linux Co-location
- DR included for both x86 and Linux on Z
- **$347K in savings**

Cloud Case - Costs details

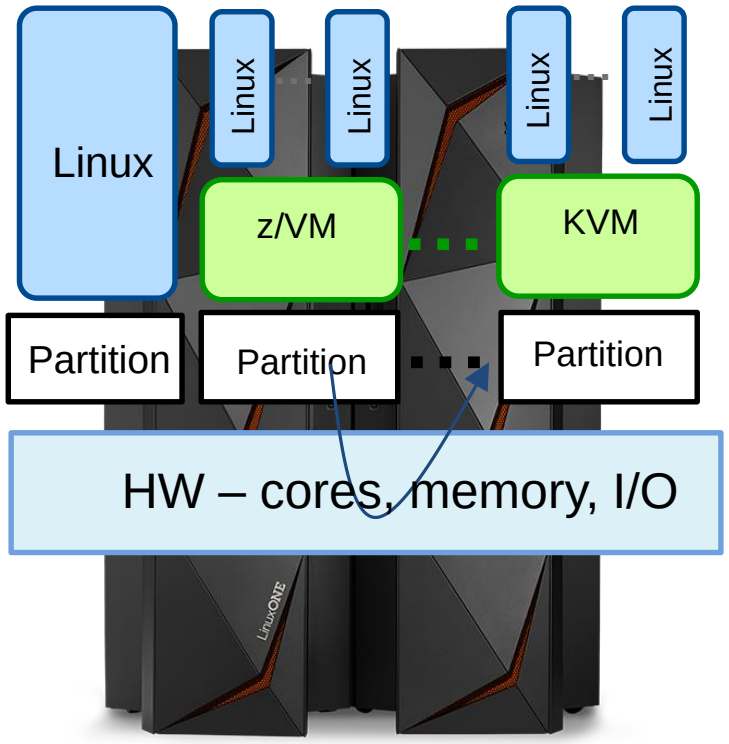


Performance comparison based on IBM Internal tests comparing IBM LinuxONE Rockhopper II with one comparably configured x86 environment and one comparably configured public cloud running general purpose virtual machines designed to replicate typical IBM customer workload usage in the marketplace. System configurations are derived from IBM internal studies and are as follows: Public Cloud configuration: total of 24 general purpose instances; x86 configuration: total of two x86 systems each with 24 Intel E5-2687 v4 cores, 192GB memory, and 2x400GB SSDs; LinuxONE configuration: total of 8 cores, 512 GB memory, and Storwize v7000 with 4x400GB SSDs. Price comparison estimates based on a 3YR Total Cost of Ownership (TCO) using publicly available U.S. prices (current as of 02/10/2018). Public Cloud TCO estimate includes costs (US East Region) of infrastructure (instances, data out, storage, enterprise support, free tier/reserved tier discounts), middleware (WebSphere Application Server ND and DB2 Enterprise Server Edition), and labor. IBM LinuxONE and x86 TCO estimates include costs of infrastructure (system, memory, storage, virtualization, OS), middleware (WebSphere Application Server ND and DB2 Enterprise Server Edition), and labor. Results may vary based on actual workloads, system configurations, customer applications, queries and other variables in a production environment and may produce different results. Users of this document should verify the applicable data for their specific environment.

Wrap Up

Linux on z and LinuxONE Key Facts to remember

	IBM LinuxONE	Commodity x86 server
Faster Performance	**5.2 GHz** (Emperor II), 4.6 GHz (Rockhopper II)	2.3 GHz (Xeon Gold 6140 – Skylake)
	• Encryption is 2.2 x's faster than Skylake • IFLs 1.9 to 2.8 x's more throughput for database applications • JAVA garbage collection 92% less processing time	
More Secure	*Per core* crypto co-processing	Crypto co-processing shared by all cores
	• LPAR is EAL5+ • Protects to FIPS 140-2 Level 4 certified (tamper proof) • Secure Service Containers has evolved to Hyper Protect appliances	
More Reliable	Mean time to fail is measured in decades	
	• High priority workload receives resource precedence • Idle cores for automatic fail over with no disruption to application • Zero memory failures using RAIM	
Costs Less	Consolidate "priced per core" software	
	• Consolidate 100s to 1000s of x86 cores has huge savings	



IBM LinuxONE

IBM LinuxONE portfolio - siblings with footprint & scale differences

IBM LinuxONE Rockhopper II

A LinuxOne for Everyone

”Right-sized” to fit your needs

The world’s premier Linux server hardware for highly secure data and cloud serving

Engineered for performance and scale

Foundation for data serving and next generation applications

IBM LinuxONE Emperor II

Built on decades of proven and trusted IBM technology

Built for the cloud with standardization and simplicity

Lower cost than x86 for mission critical data serving at scale

Right-sized for your business needs

Why Work with Mainline?